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# The Algal Genus *Gracilaria* in Australia

(Division of Fisheries—Report No. 15)

*By*

VALERIE MAY, M.Sc.
(*Division of Fisheries*)

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## SUMMARY

In accord with the war-time agar-production programme, a survey has been made of the algal genus *Gracilaria* in Australia.

All available herbarium material in Australia, and some material from New Zealand, together with other exotic specimens have been examined.

The criteria found to be of value in this study of *Gracilaria,* the difficulties encountered in this connexion, and the taxonomic procedure adopted, are discussed.

It is shown that a series of polytypic species of *Gracilaria* occurs in Australian waters. These species and their forms are described, discussed, and compared. Some species have been reduced to sub-specific status, and other forms are described as new. Forms described as new are as follows: *G. confervoides* f. *ecortica* and f. *tumida, G. lichenoides* f. *complanata, G. Textorii* f. *tenuis, G. secundata* f. *pseudoflagellifera* and f. *compacta, G. Harveyana* f. *nana.* Where possible, the relationships between Australian and various exotic species or forms are suggested.

Keys to the Australian species and forms of *Gracilaria* are given.

# The Algal Genus *Gracilaria* in Australia*

## I. INTRODUCTION

The Division of Fisheries of the Council for Scientific and Industrial Research first became interested in the study of algae when it was proposed to produce agar-agar in Australia to replace that formerly imported from Japan, but lacking since the outbreak of war. In accordance with this agar-production plan, the writer has been engaged since 1942 on the work of identifying many samples of algae, and in studying the algal genus *Gracilaria,* which is the genus most used for agar production in Australia. The result of the systematic study of this genus is embodied in the present paper. Hundreds of specimens collected by the staff of this Division have been studied, as have also the collections from the herbaria included in the following list:—

| *Herbarium source* | *Abbreviations used for reference in present paper*† |
|---|---|
| Council for Scientific and Industrial Research, Division of Fisheries, Cronulla, New South Wales. Collected by various members of staff. Collection preserved in formalin | CSIR |
| National Herbarium, Melbourne, Victoria. (This collection includes Sonder's personal herbarium, and so is of particular value. It also includes more exotic specimens than are available in the other herbaria) .. .. | MEL |
| National Herbarium of New South Wales, Sydney, New South Wales. (This herbarium was for many years in charge of A. H. S. Lucas, who is largely responsible for its good order) .. .. .. .. .. .. | NSW |
| Queensland Herbarium, Brisbane, Queensland .. .. | BRI |
| Herbarium of J. B. Cleland, University of Adelaide, South Australia .. .. .. .. .. .. | JBC |
| Herbarium of A. H. S. Lucas, Council for Scientific and Industrial Research, Division of Plant Industry, Canberra, Federal Capital Territory .. .. .. .. | AHSL |
| Herbarium of Tasmanian Museum, Hobart, Tasmania .. | HO |
| Herbarium of the University of Melbourne, Victoria .. .. | UM |
| Herbarium of the University of Sydney, New South Wales .. | SYD |
| Herbarium of the University of Tasmania .. .. .. | TAS |
| Herbarium of the University of Western Australia .. .. | UWA |
| ‡Material *ex* herbarium of the Department of Scientific and Industrial Research, Botany Division, Wellington, New Zealand .. .. .. .. .. .. | DSIR |
| ‡Material *ex* herbarium of V. W. Lindauer, Pihama, Taranaki, New Zealand .. .. .. .. .. .. | VWL |
| Herbarium of Valerie May .. .. .. .. .. | VM |

* Typescript received, February 4, 1946.

† These abbreviations are those suggested by Lanjouw (1939), with additions.

‡ These specimens are now located in the herbarium of Valerie May.

All available sheets of *Gracilaria* from Australia have therefore been examined, and also some from New Zealand and certain other countries. The areas in which I have collected personally are limited to the coasts of New South Wales and Southern Queensland.

In the past, detailed studies in algal taxonomy in Australia have been largely neglected; this is illustrated by the fact that among the herbarium specimens which were labelled as species of *Gracilaria,* I have received specimens of, among others, *Hymenocladia, Gloioderma, Eucheuma, Dicranema, Laurencia, Chondria, Hypnea, Rhabdonia, Sarcocladia, Erythoclonium, Corallopsis,* and even *Sporochnus.* With these inaccuracies at generic level, the specific determinations must necessarily be accepted with distrust. In studying *Gracilaria* I have worked in the field where possible, and have gradually built a picture of the populations of *Gracilaria,* their discontinuities (sensu Du Rietz 1930) and their gradations. At first all slightly differing specimens were considered as different forms, but later, after the examination of more material, many of these forms were recognized as together representing populations of the rank of forms or species. When these latter units were recognized they were related to the few type or authentic specimens available to me, and to descriptions and illustrations in the literature.

It is realized that a world study of the genus would be more satisfactory, but the facilities for this are not available in Australia, and so this study has of necessity been limited to Australian plants. Where possible the relationship between Australian and various exotic species or forms is considered and discussed.

## II. DIAGNOSTIC CRITERIA

Of the criteria which may be used in distinguishing species of *Gracilaria,* I have found the structure of the thallus as seen in transverse section to be the most satisfactory, and in this paper the preliminary division of species has been based on this character. Since the structure of the thallus varies from base to apex, it is obvious that the position on the plant from which the transverse section is taken should be standardized. Near the apex of the plant the tissue is undifferentiated, and lower down the plant the stage of maturation varies progressively. For the purposes of the following descriptions therefore the sections have always been taken from near the base of the plant. In some few cases (e.g., sometimes in *G. confervoides*) it has been found that a small " juvenile " slender basal portion of the plant persists below the main structure; in this case the section should be taken from the base of the more matured (normal width) portion of the plant.

In one group of species (represented by *G. lichenoides,* Fig. 3, and *G. confervoides,* Fig. 1) the thallus in transverse section shows a central tissue of a few relatively large angular cells. This abuts fairly abruptly on to a narrow (perhaps single-layered) peripheral zone; even though a degree of gradation in cell size may occur among the central cells themselves, this does not obscure

the sudden junction next to the sharply distinguished peripheral tissue. In this group of species generally the contents of the central cells are not dense-granular. This group constitutes the series MACROCYSTIDEAE (J.Ag.) emend.

In the other group of species (represented by *G. secundata,* Fig. 8, and *G. furcellata,* Fig. 9) the thallus in transverse section shows a series of minute peripheral cells, grading towards the largest cells at the centre; cells are numerous and all appear more or less rounded. With this structure is generally associated dense granular cell contents. This group constitutes the series MICROCYSTIDEAE (J.Ag.) emend.

The species belonging to each of the two groups, Macrocystideae and Microcystideae, are shown in Diagram 2, where their suggested relationships are indicated.

It appears probable that all Australian species of *Gracilaria* can develop secondary cortical tissue of regularly arranged, superimposed, small, box-like cells. In species of the Microcystideae there is often a copious development of this tissue (Fig. 9). On the other hand, in the Macrocystideae this tissue does not, except in the case of injury, consist of more than two or three layers of cells, if any, and then only at the very base of the plant. This superimposed tissue is clearly distinguishable in both transverse and longitudinal sections.

The character which has proved next in value for distinguishing species is the tuftiness or otherwise of the plant. In some species the growth of each branch is limited, thus producing tufts of branches, each branch being of approximately the same length, and the whole plant being of compact habit; in other species the growth is indefinite and the branches are very variable in length, so that the habit of the plant is diffuse.

Another character which has proved valuable is the degree of uniformity in width of the branch. Some species are of relatively uniform width throughout, while others show a marked and consistent thickening towards the base.

The general habit, degree and form of branching, amount of proliferous growth, acuteness of branch apices, and texture of thallus, are also useful criteria. The presence or absence of a constriction at the insertion of a branch on the thallus varies considerably in a single plant, so that this character is of only minor value. Generally there is no such constriction in a flattened thallus.

The size and shape of the cystocarp is not of particular value for species delineation within the genus, since it varies within a single specimen. This subject is discussed further under *G. confervoides.*

Some characters seem to the writer to have been too strongly emphasized in the past. For instance, a flattened as compared with a terete thallus is a difference which is more apparent than fundamental. It is for this reason that the sub-generic names *Plocaria* (Nees)J.Ag. and *Podium* J.Ag., which were based primarily on whether the thallus was flattened or terete, have not been recognized in the present paper. Within one species, e.g., *G. compressa,* is found

a range of forms from flat to terete (Weber van Bosse 1928), while a flattened form of the usually terete *G. lichenoides* is described in the present paper. However, in some cases, e.g., *G. Textorii,* flattening of the thallus is a useful character.

Colour has been used extensively as a character in algal descriptions, but appears to be unreliable; for example, in growing specimens of *G. confervoides* I have found some branches vivid red, while other branches of the same plant were definitely green. In all species bleaching may occur so that a plant, or portion of it, may become white if exposed to sunlight.

Size is of limited usefulness, gross differences only being reliable. Measured limits have proved rather misleading, and Plate 13, Fig. 1, shows the variation that may occur in a single plant. Until the size of the plant under varying environmental conditions is known, its absolute limits of size cannot be determined. Algae appear to be particularly responsive in size to environment; May (1938) showed that in a species of *Ectocarpus,* cell size must alter by more than 37 per cent. before it attains any statistical significance.

The relative thickness of the walls of the cells as shown in transverse section of the thallus is unreliable as a criterion, since this generally increases toward the base of the plant.

In a few cases the application of the accepted criteria is difficult, as the distinctions are not clear-cut. These cases are discussed in detail under the species or form concerned.

## III. TAXONOMY

The recognition of discrete species in the genus *Gracilaria* is particularly difficult. The wide range of variation shown by a single form according to its environment and location, and the absence of clear discontinuities between species, together make the taxonomy of this genus particularly baffling; it would scarcely be satisfactory, however, to classify as a single species all the diverse forms which exist.

Working on limited herbarium collections alone, it would be possible to devise an enormous number of different species and forms. When such a scheme is applied in the field, however, it becomes unsatisfactory and unreliable. As Taylor (1928) says, speaking of *G. Blodgettii* Harv., "it appears sufficiently distinct in typical specimens, than which little more can be claimed in this genus." It appears that within the genus *Gracilaria* there has been an excessive number of species described and the result of more intensive work has been to reduce the number of species recognized. Many old species are found to represent merely forms, i.e., are of lesser rank and intergrade towards allied forms.

The recognition of polytypic species (Huxley 1940; Mayr 1942), composed of geographical and ecological forms which intergrade, is in conformity with the biological concept of the species. This is accepted by the writer as being more accurately representative of conditions in nature than is the recognition

of species as being artificially separated groups, differing slightly from, and intergrading toward each other. Under a polytypic species is recognized a biological unit of varied aspect throughout its range, but one which shows discontinuities with neighbouring species, and is biologically isolated, at least largely, from them. This unit is relatively easily recognized and clearly defined by virtue of its biological isolation; its component units can, if necessary, be distinguished with trinomial nomenclature, but these sub-specific epithets can be ignored when the separate elements in the species do not require to be distinguished, and so they do not impede the worker on other branches of biology by making necessary the use of an excessive number of minor appellations.

In this paper a species is regarded as composed of its component sub-specific parts. Of these the typical form is regarded as fundamental for the species in the same way as the type species is of basic importance for the genus.

In the following enumerations, under each species name is given a reference to the original publication of that name, together with other references or synonyms which apply to the species as a whole. Under each sub-specific appellation are listed references and synonyms which appear to apply to that section only of the species.

Where the description given with the original publication of the specific name appears to apply either to merely a section (the typical form) or to all of that species, the original reference is repeated under both the specific and sub-specific names. For this " typical " sub-specific unit, the writer has followed the recommendations of Sprague (1939), and the sub-specific epithet is one repetitive of the specific epithet. In all cases the typical sub-specific unit is regarded as based upon the original type specimen for the species, and so the sub-specific epithet is referred to the authority of the original author in his basic meaning of the species (quoted as " sensu orig."). Thus, for example, in *G. confervoides* (L.) Grev. the typical sub-specific unit is regarded as being *G. confervoides* f. *confervoides* (L. sensu orig.) May; here Linnaeus' and Greville's references are given under both specific and sub-specific headings.

The category used for the sub-specific unit in this paper is, in most cases, " form " (= f. = forma). Where an earlier sub-specific epithet in the category " variety " (= var. = varietas) already exists, and where there is an absence of extensive collections of the plant in question (*G. lichenoides* var. *constricta* Zan.), the varietal status has not been changed.

The distribution of forms is not always correlated sufficiently with geographical factors to warrant the use of the category sub-species; in fact the determining factor sometimes appears to be purely ecological. For instance, *G. confervoides* f. *gracilis* occurs in numerous isolated areas under similar ecological conditions. Since these communities are not in direct contact with each other, they cannot be regarded as *together* in process of evolving a new geographically isolated species. It is of course possible that these ecologically

separated forms may prove to be merely phenotypic, but in the absence of evidence to this effect such relatively distinctive and widely distributed sub-specific units should, it seems, be given some taxonomic recognition. In the present paper the status used for all such units is form.

## IV. METHOD OF PRESENTATION OF RESULTS

A key to the Australian species of *Gracilaria* is given on page 17. Below each species description is given a key to the forms of that species so far found in Australia.

All specific names of *Gracilaria* which are mentioned in the text are indexed at the end of the paper.

Under each specific and sub-specific epithet heading are listed references and synonyms for that epithet (see also page 11). These lists include the main references and any new names published with reference to Australian collections. A fuller list of synonyms, including those referring to early extra-Australian publications will be found in De Toni (1897, 1924), when cited.

Immediately beneath these references are given details of some authoritatively labelled material which has been available to the writer. These citations are headed " Standard Specimens Examined."

Under each species of *Gracilaria* discussed in the present paper are given the characters which are constant throughout all forms and varieties of that species. The distinguishing characters of each form or variety are described in the discussion of that sub-specific unit.

Under each form or variety are cited the localities from which it has been collected in Australian waters, arranged in order of the State in which the collection was made. Under each State the localities given are arranged in order: from north to south in Queensland, New South Wales, and Western Australia; from east to west in Victoria and South Australia; and in alphabetical order in New Zealand and Tasmania. Herbarium sheets for which location information is incomplete are cited at the beginning of each list.

Specimens are cited with locality, collector or former herbarium, and number, date, and then the herbarium (or herbaria when duplicate specimens are known to occur) together with herbarium number (if any). Abbreviations used for herbaria names and particular collection are given on page 7. The abbreviation (Alg. Muell.) indicates that the label reads " Algae Muellerianae, Curante J. G. Agardh distributae." High and low water marks, and low-tide level are abbreviated to H.W.M., L.W.M., and L.T.L. respectively.

An additional list of localities is given, referring to material—usually poorer samples and less likely to be permanent—which is bottled and is stored at the C.S.I.R. Fisheries Division, Cronulla, New South Wales.

## V. RELATIONSHIPS AND DISTRIBUTION

A chart such as that shown in Diagram 2 seems the clearest way to illustrate the species complex. In this diagram each species is seen to consist of a number of forms which grade into each other, and towards forms of other species. In some cases a certain form (a) of one species (A) would show closer affinity to a form (b) of a different species (B) than it does to another form (a') of its own species (A). In some cases a form (x) might equally well be considered as a form of either of the two species (A) and (B).

It seems significant that the geographical distribution differs in the two species-groups which have been distinguished; the Macrocystideae group of species being developed particularly in the north-east, and the Microcystideae group of species in the south-west, of the continent. (Unfortunately there is insufficient information on the algal flora of most of the north or north-west areas of Australia.)

Geographical distribution within a species is best illustrated by a study of *G. lichenoides,* which, with its forms, inhabits the north-east shores of Australia. Of three intergrading forms of *G. lichenoides* (f. *Lemania,* f. *taenioides,* and f. *lichenoides*), f. *Lemania* grows in the cooler waters of New South Wales, f. *taenioides* is prevalent in Southern Queensland, and f. *lichenoides* occurs still further north; similarily two other intergrading forms of this species (f. *Lucasii* and f. *coronopifolia*) appear to grade in distribution over this same area.

Genetical studies would be necessary in order to determine the degree, or absence, of crossing between the different species and forms of the genus. The distribution in Australian waters of the various forms and species as at present known is shown in Diagram 1.

Owing to the present lack of knowledge of the algal flora of the far north and north-west waters of Australia, it is premature to speculate on the historic distribution of the genus *Gracilaria* in Australia. Further, of the species recognized here, many are the same as, or closely related to, species from other parts of the world, familiarity with which would be needed to reveal development within the genus. It seems possible, however, that the Microcystideae group is the more primative group of species, since the structure of thallus characteristic of this group may appear in the juvenile stages of a species of the Macrocystideae (*G. confervoides*).

## VI. EARLIER PUBLICATIONS COMPARED WITH PRESENT FINDINGS

Two Australian species, originally recorded in the genus *Gracilaria, G. dactyloides* Sond., and *G. Ramalina* Harv., both of Western Australia, were later transferred to the genus *Hymenocladia,* where they have been retained (Agardh 1870, 1876).

| Series. | Species and Forms. | Queensland | New South Wales | Victoria | Tasmania | South Australia | Western Australia | New Zealand | Norfolk Island | Lord Howe Island |
|---|---|---|---|---|---|---|---|---|---|---|
| Macrocystidae | 1. *G.confervoides*— f.*confervoides* .. | × | × | | | | | | | |
| | f.*ecortica* .. .. | × | × | × | × | | × | | | |
| | f.*tumida* .. .. | × | × | | | | | | | |
| | f.*gracilis* .. .. | × | × | × | × | × | × | × | | |
| | 2. *G.lichenoides*— f.*lichenoides* .. | × | × | | ? | ? | | | | |
| | f.*taenioides* .. | × | × | | | | | | | |
| | f.*Lemania* .. | × | × | | | | | | | |
| | f.*Lucasii* .. .. | × | × | | | | | | | × |
| | f.*coronopifolia* .. | × | | | | | | | × | |
| | var.*constricta* .. | × | | | | | | | | |
| | f.*polyclada* .. | × | | | | | | | | |
| | f.*complanata* .. | × | | | | | | | | |
| | 3. *G.Howensis* .. .. .. | | | | | | | | | × |
| | 4. *G.Textorii*— f.*Textorii* .. .. | × | × | | | | | | | |
| | f.*tenuis* .. .. | × | | | | | | | | |
| | 5. *G.pannosa* .. .. | | | | | | × | | | |
| Microcystidae | 6. *G.canaliculata* .. | × | | | | | | | | |
| | 7. *G.secundata*— f.*secundata* .. | | × | × | | | | × | | × |
| | f.*flagellifera* .. | | | × | × | | | × | | |
| | f.*pseudoflagellifera* .. | | | | × | | × | × | | |
| | f.*compacta* .. | | | | | | | × | | |
| | 8. *G.furcellata*— f.*furcellata* .. | | | × | × | × | × | | | |
| | f.*ramulosa* .. | | | | | | × | | | |
| | 9. *G.Harveyana*— f.*Harveyana* .. | | | | | × | × | | | |
| | f.*nana* .. .. | | | | × | | | | | |

DIAGRAM 1.—This diagram indicates the distribution in Australian and nearby waters of forms and species of *Gracilaria*. The query marks represent records in the literature for which the plants were not available to the present writer.

In 1901, J. Agardh published a revision of the genus *Gracilaria,* the latest general taxonomic work on this genus. In this he described two new species (*G. bifaria* and *G. paradoxa*) from Australia, but as these are without illustration, and as there are no specimens of them available in Australia, they are treated in the present paper as " species incertae sedis."

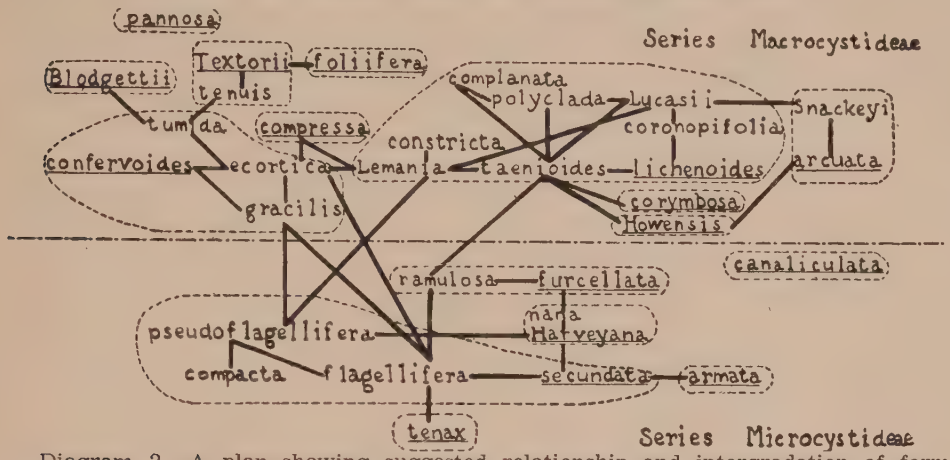


Diagram 2.—A plan showing suggested relationship and intergradation of forms and species of *Gracilaria* discussed in this paper. Specific names are underlined; form or variety names are not. Lengths of lines between forms do not necessarily represent the degree of relationship. A broken line surrounds each species, monotypic or polytypic.

In 1909 Lucas published a reference list of the Fucoideae and Florideae of Australia, in which he listed fifteen species of *Gracilaria;* he has since recorded one new species from Lord Howe Island (Lucas 1935). In the present paper, of these sixteen species, four (*G. Lucasii, G. taenioides, G. polyclada,* and *G. ramulosa*) are now reduced to the rank of form; two (*G. fruticosa, G. aculeolata*) are recorded as " species incertae sedis "; one (*G. spinescens*) has proved in part a form and in part an incorrect identification (for *G. secundata*); one (*G. corniculata*), at least as regards material from the Australian mainland, has been shown to belong to another genus; and the remaining eight species are recognized here, together with one other (*G. confervoides*) which was recorded as in " Australia " by J. Agardh (1901). The records of *G. compressa* in Australia are discussed on p. 32.

There are thus now recognized, in the present paper, nine species of *Gracilaria* in Australian and nearby waters, each species consisting of from one to eight forms. There are also five species listed as " species incertae sedis " some of which, it is suggested, may be merely forms of other (recognized) species. The nine species here accepted consist in these waters of 25 forms, seven of which are described for the first time in this paper.

From New Zealand Laing (1939) records two species of *Gracilaria* (*G. confervoides* and *G. flagellifera*), known from that country with certainty, and eight species suspected of occurring there. Of these ten species, many are dealt with in this paper: *G. secundata* has been recognized from New

Zealand; *G. lichenoides* is considered likely to occur there; *G. flagellifera* and *G. ramulosa* are reduced here to the status of form; much at least of so-called *G. Harveyana* and *G. confervoides* from New Zealand is considered to have been a misnomer for *G. secundata* f. *pseudoflagellifera,* and it is suggested that *G. disticha* is likely to be a misnomer (for *G. lichenoides?*). Further, perhaps *G. dura* is a misnomer for *G. secundata,* while *G. polycarpa* probably is merely a geographical form of *G. Textorii.* In this paper *G. paradoxa* is regarded as a " species incertae sedis " although Yendo (quoted by Laing 1939) suggested that it is perhaps a *Sarcodia.* These suggested misnomers are discussed under the species concerned.

From Norfolk Island (Laing 1900, 1905), no species of *Gracilaria* has previously been recorded. In the present paper *G. lichenoides* f. *coronopifolia* is recorded from that locality.

From Lord Howe Island (Lucas 1935) only one species of *Gracilaria* (*G. Howensis*) has previously been recorded. In the present paper *G. lichenoides* f. *Lucasii* and *G. secundata* f. *secundata* also are recorded.

## VII. DESCRIPTION OF GRACILARIA GREV.

*Gracilaria* Grev. 1830, *Alg.Brit.,* 121; De Toni 1897, *Sylloge Algarum,* 428-30; De Toni 1924, *Sylloge Algarum,* 249-75; J. Agardh 1901, *Sp.* 3 (4), 32-102.

The genus *Gracilaria* is widely distributed throughout the world, growing attached to a substratum in the littoral or sub-littoral zone. It is a red alga, free-living, generally erect and freely branched. It is characterized by the production of an external, sessile, hemispherical or beaked cystocarp with a thick pericarp, a single ostiole, and ellipsoidal spores arising from a large parenchymatous placenta. Spermatia occur in superficial sori or in conceptacle-like depressions in the thallus surface. The tetraspores are cruciate, scattered in the periphery of the thallus. The thallus is solid " parenchymatous ", and consists of large central cells, a varying development of intermediate cortical cells, and an external layer of smaller peripheral cells which form the assimilating layers. In longitudinal sections the cells are not, or only slightly, elongated. A representative longitudinal section of a thallus is illustrated by Oltmanns (1904, p. 549, fig. 334).

This genus belongs to the group of algae which have a central axis, as was pointed out by Kylin (1930). However, the main axis is very soon lost in the so-called parenchymatous thallus.

In the development of the cystocarp (Kylin 1930), the carpogonial filament is two-celled and its supporting cell bears sterile filaments. These cells later all fuse with each other and with certain adjacent cells. From the fusion cell the gonimoblast filaments grow toward the surface of the thallus, and of this globose mass all cells except those at the centre develop into carposporangia. Carpospores are shed beneath the pericarp and liberated via the ostiole.

J. Agardh (1901) pointed out important differences in the structure, as shown in transverse section, of the thalli of different species of *Gracilaria.*

He recognized several different structures which he used to differentiate the sections of *Gracilaria*. Of these series of sections two only, viz., *Macrocystideae* and *Microcystideae,* are recognized in the present paper. These, as now modified, are described on page 8. Those species which J. Agardh placed in other sections are now regarded as belonging to one or other of the above-mentioned sections.

*Gracilaria* shows close affinity with the genus *Corallopsis* Grev. from which it differs mainly in the latter possessing a very much greater development of strictures or constrictions in the axes.

The genus *Gracilariophila* Setch. and Wilson is closely allied to *Gracilaria* but differs from it in its parasitic habit.

**Key to the Species of Gracilaria in Australia**

1. Thallus in transverse section showing sudden transition from small peripheral to larger central cells .. Series MACROCYSTIDEAE
   - Habit indefinite; thallus terete .. .. .. 1. *G. confervoides* (page 18).
   - Habit tufty to half-tufty; thallus sometimes flattened.
     - Elongated proliferations (other than branches) not produced.
       - Thallus in transverse section with six or more large central cells in any one diameter; plant usually terete, tufty, rarely exceeding 2 mm. in width.
         - Thallus usually less than 1·5 mm. in width, sometimes flattened .. 2. *G. lichenoides* (page 27).
         - Thallus about 2 mm. in width, terete .. .. .. 3. *G. Howensis* (page 39).
       - Thallus in transverse section usually with three large central cells across one diameter; thallus almost invariably flattened .. .. .. 4. *G. Textorii* (page 41).
     - Elongated proliferations (other than branches) produced from the edges of a flattened thallus .. .. .. 5. *G. pannosa* (page 44).

1'. Thallus in transverse section showing gradation in size of cells from centre to periphery .. .. Series MICROCYSTIDEAE
   - Dried plant bearing papillose rugose proliferations; plant coarse .. .. .. 6. *G. canaliculata* (page 45).

Dried plant not bearing papillose rugose proliferations.

Branching dichotomous and imbricate; plant tufty; branch width often increasing greatly toward the base .. .. 8. *G. furcellata* (page 53).

Branching irregular or secund, distichous or trichotomous, not dichotomous; branching less imbricate; plant tufty or of indefinite habit.

Branching usually secund but sometimes distichous or irregular; habit tufty to half-tufty; branching somewhat imbricate; branch width relatively uniform 7. *G. secundata* (page 46).

Branching irregularly alternate; growth half-tufty; branching not imbricate; branch width increasing greatly toward the base .. 9. *G. Harveyana* (page 56).

## VIII. ENUMERATION OF SPECIES, FORMS, AND VARIETIES

### 1. Gracilaria confervoides (L.) Grev.

*Gracilaria confervoides* (L.) Grev. 1830, *Alg.Brit.*, 123; J.Ag. 1852, *Sp.* 2, 587; J.Ag. 1876, *Epicr.*, 413; De Toni 1897, *Sylloge Algarum*, 431-2; *Fucus confervoides* L. 1764, *Sp. Pl.*, 2, 1629; Turner 1809, *Fuci*, tab. 84.

Extremely variable in size and colour and in the habitat in which it may be found. Habit of growth indefinite, the branching irregular, often secund or dichotomous, the branches fairly uniform in width throughout the plant but tapering at the apices. Thallus terete and in transverse section showing large parenchymatous, usually thick-walled cells of the central tissue fairly sharply defined from the cortical or peripheral small cells (Macrocystideae; Figs. 1 and 2). Colour from purple, red, green, to yellow, and different branches of a plant on occasion a different colour. Plant generally elastic in texture, adhering moderately to paper on drying. Cystocarp generally hemispherical.

Storms sometimes result in plants of this species being buried under sediment. Forma *confervoides* is sometimes apparently covered by sand to a depth of a foot or more without detriment, the exposed portion continuing growth. Often a large portion of buried plant underlies the small portion showing above sand level. Where the covered portion is in mud it is frequently black in colour. Frequently also this basal portion is of a juvenile form.

A series of rhizoidal growths, forming a small disk, attaches *G. confervoides* to the substrate. In many specimens, particularly of f. *gracilis*, the substrate is a whelk, though by no means all whelk-beds bear *Gracilaria*. In mature

plants of f. *confervoides* and f. *ecortica* a certain fasciate branching (Plate 1, Fig. 2) often occurs, especially near the basal portion of a plant. Fully established plants, even those apparently growing in sand, are attached to a hard substrate, as is shown when underlying portions are excavated; whelks, mussels, twigs, or worm casts, and sometimes rocks, are the usual substrata. This fact leads to hopes of future commercial cultivation of this agar-rich species by "planting" suitable substrate, as is now done for oyster cultch and as the Japanese do for other algae. It is perhaps noteworthy that where commercial handling of the plant has resulted in pieces frequently being dropped overboard from jetties, a secondary bed has at times become established.

FIG. 1.—Transverse section of the thallus of *G. confervoides* f. *confervoides*. The sudden junction next to the central tissue is clearly shown. Approx. × 40.

FIG. 2.—Transverse section of the thallus of *G. confervoides* f. *ecortica*. The peripheral zone is much less developed than in f. *confervoides*. Approx. × 40.

The forms f. *confervoides,* f. *ecortica,* and f. *tumida* of this species are frequently torn from their substrate by storms, when they may be carried out to sea or rolled ashore on the strand line. Sometimes they are washed into sheltered pockets of water and there the detached portions appear to continue living for quite a while.

*Fucus confervoides* was divided by Turner (1809, tab. 84) into a number of varieties some of which (*β. procerrima, γ. albida,* and *δ. geniculata*) were retained under *Gracilaria confervoides* by Greville (1830) and Harvey (1849). Only two varieties (*procerrima* and *gracilis*) were retained by Batters (1902) and Newton (1931); and of these only f. *gracilis* is recognized in the present paper. Most of Turner's original varieties of this species thus appear to represent only individual variations in the stage or size of growth of the plant at the time of examination.

Sonder (in Mueller 1880) listed a variety *secundata* (no authority) of *G. confervoides* from Cooktown, Queensland. From notes in Sonder's herbarium (Herb. MEL) it seems possible that this undescribed variety of *G. confervoides* was to have been based by Sonder on Harv. Alg. Aus. Exsicc. No. 325. This

specimen, however, is Harvey's *Gracilaria secundata,* which is not known from Queensland. In Bailey's Catalogue (1912) *G. confervoides* var. *secundata* is given under the authority of Mueller, and refers to the above quoted publication. Thus the var. *secundata* of *G. confervoides* appears to be a nomen nudum of Mueller (or Sonder in Mueller) and as such should be disregarded.

The forms of *G. confervoides* which I here recognize are not absolutely distinct entities, because even a single plant may show transitional stages between two forms. However, the extreme forms are clearly distinguishable, and these forms do occur in different proportions under different habitat conditions. Okamura (1916-23) also regards this species as altering markedly according to external conditions—he records it as being smaller on rocks on open shore and often very long in sheltered places with brackish water. Diagram 2 shows how the forms found in Australia intergrade within the species *G. confervoides.*

In 1926 Sjostedt corrected some earlier observations made by Phillips (1925) and described in some detail the anatomy and development of three species of *Gracilaria.* One of these species he erroneously referred to *G. robusta,* and this plant later became the basis for *G. Sjostedtii* Kylin 1930. In his paper Sjostedt mentions that he examined *G. confervoides* (L.) Grev. as well as *G. robusta* from Californian collections. Smith (1944) recognized *G. Sjostedtii* but not *G. confervoides,* from the Monterey Peninsula, Pacific Coast, plants of U.S.A.

These two species, *G. confervoides* and *G. Sjostedtii,* are distinguishable, according to Sjostedt (1926), since *G. confervoides* has a lesser development of cortex, and in the cystocarp there is developed a series of connecting filaments (tubular cells) between the pericarp and the carposporangium. These cells provide nourishment for the developing tissue, so their presence is correlated with an absence of granular food stores in the so-called placental tissue. Further, in *G. confervoides* the cystocarps are recorded as larger and more "necked" or constricted at their junction to the axis.

Oltmanns (1922, p. 423, fig. 608) had previously illustrated these connecting filaments in the cystocarp of *G. confervoides.*

In the present paper it is shown that within a single specimen there is variation in the amount of development of the cortex (see under description of f. *ecortica*) and in the size and shape of the cystocarps. Thus the main distinction between *G. confervoides* and *G. Sjostedtii* is the presence or absence of the tubular cells between the pericarp and carposporangium and the relative amount of food stored in the so-called placental tissue. These tubular cells have been observed in the cystocarps of Australian specimens, which are therefore referred to *G. confervoides.*

*G. confervoides* in Australia occurs in estuarine waters. It is interesting to note that E. Yale Dawson (1945) records that in San Diego County, California, *G. confervoides* occurs in estuarine waters, while *G. Sjostedtii* occurs in "the littoral on the open coast".

Under *G. lichenoides* there is discussed the manner in which this species links with and differs from both *G. confervoides* and *G. compressa.*

*G. confervoides* is listed by Laing (1939) as growing in New Zealand, but the present writer doubts this record. A portion of a New Zealand specimen No. 237 ex Herb. R. M. Laing from Akaroa foreshore 5/2/35, det. R. M. Laing, was sent to the writer by Miss Lucy Moore, of D.S.I.R., New Zealand. She remarks that this is " the only surely R.M.L. determinavit sheet we have " of the species; this plant is not *G. confervoides,* but *G. secundata* f. *pseudoflagellifera.* It seems likely that this form is the one that has been known erroneously in New Zealand as *G. confervoides.*

*G. confervoides* appears to be fairly cosmopolitan in distribution, apparently showing little or no differentiation into geographical sub-species. As shown in this paper, however, it does have ecological races.

Reproductive structures may be found on some plants of this species at all times of the year. During the winter months of May, June, and July there is least reproductive activity, while the peak in activity is reached in December, January, and February, with a lesser peak in late August to September. The various forms show little difference in this regard.

The vegetative bulk of *G. confervoides* varies from time to time; storms may obliterate a bed of this plant, or on the other hand they may uncover an area which had been previously buried. Generally, however, maximum vegetative, as well as reproductive, development occurs during the summer months.

*Key to the Forms of* G. confervoides

1. Plant fine, diameter not exceeding 0·35 mm. .. f. *gracilis* (page 25).

1′. Plant not fine, diameter usually 0·7 mm. or more.

2. Cortex thick .. .. .. .. f. *confervoides* (page 21).

2′. Cortex thin or absent.

3. Plant coarse, diameter wide (up to 1·3 mm.) .. .. .. .. f. *tumida* (page 24).

3′. Plant not coarse, diameter moderate (about 0·7 mm.) .. .. .. f. *ecortica* (page 22).

**G. confervoides f. confervoides (L. sensu. orig.) stat. nov.**

*Gracilaria confervoides* Grev. 1830, *Alg.Brit.,* 123; Harvey 1846-51, *Phyc. Brit.,* pl. 65; Okamura 1916-23, *Icones,* 4, 1-2, tab. 151; *Fucus confervoides* L. 1764, *Sp. Pl.,* 2, 1629.

A form which may be described as typical for this species is illustrated in Plate 1, Fig. 1, and in Fig. 1. This plant agrees with the illustrations and descriptions given by Okamura (1916-23, vol. 4, p. 1-2, pl. 151) and Harvey (1846-51, pl. 65). This form is also represented by an exotic alga (examined

by the author) distributed as No. 547, *G. confervoides,* from Sylt Island, collected and determined by Kuckuck, and now in the National Herbarium of N.S.W.

Habit lax and growth indefinite, the branching generally from one side though occasionally dichotomous or alternate; secondary branches relatively few; tufts of branches or close branching absent. Plant reaching a length of 2–2½ meters or more, rarely exceeding 1 mm. in width, red, green, or purple to straw-coloured, branches of different colours being sometimes attached. Thallus in transverse section (Fig. 1) showing a thick development of the cortical layer of small cells, with an abrupt transition to the large central cells, about five of which generally occur in any diameter; walls of individual cells usually thick; contents of the central cells sometimes granular.

Forma *confervoides* has a greater degree of elasticity than other Australian forms of this species. At the base of this form the juvenile thin form (f. *gracilis*) may be found, when a transition may be shown leading from f. *gracilis* to f. *confervoides* (Plate 1, Fig. 1).

Forma *confervoides* occurs in quiet estuarine waters, and is generally on a rather sandy substrate, often on sand overlying mud. This is the form that has been used most for agar production in Australia. For this industry it has been collected in large quantities from Botany Bay, Middle Harbour, and Port Hacking, New South Wales, during the years 1943-5. Hundreds of specimens have been examined from these three areas alone.

*Localities*

*Queensland.*—Morton Bay: Moreton Big Banks, 12/1943 (VM 681, 685); Stradbroke Island, Amity Banks Flats, 11/1943 (VM 617); Stradbroke Island, Swan Bay, 11/1944 (VM 220).

Additional localities C.S.I.R.—Sandy Straits (near Maryborough).

*New South Wales.*—Wallis Lake, 8/1944 (VM 170, 171). Port Jackson: Athol, 3/1928 (VM 901); near Double Bay, growing in sand, 7/1944 (VM 736); Farm Cove, Lucas, 1/1914 (AHSL); Farm Cove, trawled, 7/1944 (VM 733, 734, 735); Forty Baskets, near Manly, mud flat at L.T.L., 11/1945 (VM 1048); Middle Harbour, trawled, 12/1944 (VM 222, 225, 233, 238). Botany Bay: Lucas, 1/1912 (AHSL); Lucas, 12/1912 (NSW); trawled, 9/1943 (VM 127); trawled, 9/1944 (VM 112, 113, 114); Doll's Point, growing on rock, 9/1944 (VM 632); Heads, 3 fathoms, Lucas, 10/1934 (AHSL, SYD); Kurnell, trawled, 11/1944 (VM 180, 181, 182, 183, 184); Sandringham, trawled, 11/1944 (VM 175); Sans Souci, Lucas, 7/1902 (NSW, SYD); Towra, drift, 3/1944 (VM 305). Port Hacking, near Bar, trawled, 6/1945 (VM 815).

Additional localities, C.S.I.R.—Angourie, Tuggerah, Jervis Bay, Conjola, Burrill, Bateman's Bay, Barragoot, Eden.

**G. confervoides f. ecortica forma nov.**

Affinis f. *confervoidi,* sed sectio transversa rami non monstrat amplum stratum corticale minute cellulosum.

Differs from f. *confervoides* merely in the anatomical structure as shown in the transverse section of the thallus, and in the habitat in which it is most prevalent.

These two forms are not distinguishable in the field, except at times by the inconstant character of colour, f. *ecortica* being more usually green, while f. *confervoides* is more often yellow-red. In transverse section of the thallus, f. *ecortica* lacks the well-developed cortical region of f. *confervoides* (Fig. 2); instead a single peripheral layer of cells impinges directly on to the central cells, or there are one, two, or even three layers of small cortical cells; cell walls generally thinner than those of f. *confervoides.*

Forma *ecortica* grades imperceptibly into f. *confervoides.* It appears that in both forms the tissue differentiates behind the growing apex; in f. *ecortica* no great differentiation of cortex takes place, but in f. *confervoides* the differentiation is considerable. Varying degrees of differentiation of cortex are found, giving all intermediate structures between the two forms. Both forms may occur together, though the proportion of each in the population varies with the habitat. Forma *ecortica* occurs particularly on a muddier substrate than does f. *confervoides.* It is noteworthy that in Moreton Bay, Queensland, f. *confervoides* occurs near the eastward islands, while f. *ecortica* occurs further west, being more abundantly developed towards the mouth of the Brisbane River.

In May 1930, A. H. S. Lucas collected a plant, No. 8, from Botany Bay, New South Wales, and W. A. Setchell identified it (letter 1931) as *G. confervoides.* This plant is the form type for f. *ecortica* (Herb. AHSL).

Another specimen of f. *ecortica,* No. 6, from Bridport, Tasmania, collected by F. Perrin and A. H. S. Lucas, February 1930 (Herb. AHSL) was identified as *G. confervoides* by W. A. Setchell, who says (1931 letter): "I have compared it in detail with specimens from elsewhere."

An exotic plant which appears to agree vegetatively with f. *ecortica* is one, collected at Cuba –/12/05, Baker T. Van Herman, No. 4389, and distributed as *G. confervoides* det. Farlow (Herb. NSW).

*G. confervoides* approaches *G. lichenoides* (Diagram 2), since a young plant of *G. confervoides* f. *ecortica* (of indefinite growth) and a luxurious growth of *G. lichenoides* f. *Lemania* (of tufty habit) may resemble each other, both having a similar structure as shown in transverse section of the thallus, that is, the cortex is little, if at all, developed. However, the two species can be distinguished by their habits, growth being indefinite and habit lax in *G. confervoides,* while in *G. lichenoides* the growth is definite and the habit tufty; also generally, but not always, the number of large central cells shown in a transverse section of the thallus is five in *G. confervoides* and six or more in *G. lichenoides,* throughout most of the length of the plant.

*Localities*

*Queensland.*—Morton Bay: Fisherman's Island Flats, 5/1943 (VM 731); Lihou's Bank, drift, 5/1943 (VM 730); Stradbroke Island, Dunwich, drift, 1/1944 (VM 729).

Additional localities, C.S.I.R.—Urangan.

*New South Wales.*—Port Stephens, Nelson's Bay, Fraser, 1/1931 (SYD). Hawkesbury River, Pittwater, entrance to The Basin, trawled, 12/1945 (VM 1174). Port Jackson: Balmoral, Lucas, 7/1931 (AHSL); Farm Cove, Lucas, 1/1914 (NSW, SYD); Middle Harbour, trawled, 12/1944 (VM 224, 229, 234, 245); Rose Bay, Lucas, 6/1899 (AHSL). Botany Bay: Lucas, 12/1912 (AHSL, SYD); Lucas, 5/1930 (AHSL 8); Cook's River Breakwater, drift, 3/1944 (VM 280); Sans Souci, Lucas, 6/1898 (NSW). Lake Illawarra: 7/1944 (VM 146); 9/1944 (VM 120, 121, 122); Gooseberry Island, 9/1944 (VM 117, 118, 119).

Additional localities, C.S.I.R.—Chinderah, Richmond River, Laurieton, Manning River, Lake Macquarie, Hawkesbury River (Patonga), Port Hacking, Durass, Bateman's Bay, Wagonga, Narooma.

*Victoria.*—Port Fairy, Lucas, 1/1932 (AHSL). Ocean Grove, Tisdall, 1/1898 (NSW). Port Phillip Heads, Stn. 1, Wilson, 1/1893 (NSW).

*Tasmania.*—Bridport, Perrin & Lucas, 2/1930 (AHSL 6 *et al.*, SYD).

*Western Australia.*—Albany, Lucas, 9/1928 (AHSL).

**G. confervoides f. tumida forma nov.**

Affinis f. *ecorticae,* sed frondibus latioribus (ad 1·3 mm.), differt.

A swollen or inflated form of *G. confervoides,* differing from f. *ecortica* mainly in size (diameter up to 1·3 mm.), the forms rarely even occurring on the same plant. (In herbarium specimens this difference may be difficult to see, and may generally be neglected, but in the field the two forms are easily distinguishable.) Thallus usually with thin-walled cells, always with large lumina, and, consequently, when turgid, plant very brittle. Constrictions at the insertion of the branches often well developed, more frequently present in this than in the other forms of the species.

Forma *tumida* has been found in warm waters on muddy substrates. So far it is known only from Queensland and, less frequently, from New South Wales. No. 578 (Herb. VM) is the type of this form.

*G. confervoides* f. *tumida* may at times appear similar to the fine form of *G. Textorii,* but the latter is almost invariably flattened (even if but slightly) and the number of central cells shown in a transverse section of the thallus in one diameter differs, *G. confervoides* showing not less than five, and *G. Textorii* generally only three.

From Taylor's description (1928, p. 151) it seems that the present form may approach *G. Blodgettii* Harv., recorded from Java by Weber van Bosse (1928), but the writer has not seen any authentic specimens of it.

*Localities*

*Queensland.*—Queensland, Gross (AHSL). Urangan, pools in mud flat, 8/1943 (VM 724). Moreton Bay: Canaipa Passage, 3/1945 (VM 574, 578, 584); Fisherman's Island Flat, 11/1943 (VM 725); Fisherman's Island Flat, 12/1943 (VM 726, 727, 728); Lamb Island, trawled, 5/1943 (VM 149); Woody Point, Lucas, 12/1913 (AHSL).

*New South Wales.*—Port Jackson, Rose Bay, cast up, Lucas, 6/1899 (AHSL). Botany Bay: Lucas, 2/1905 (NSW, AHSL); Taren Point, 3/1945 (VM 547); Towra, drift, 3/1944 (VM 303).

Additional localities, C.S.I.R.—Port Hacking.

**G. confervoides f. gracilis (Turn.) Grunow**

*G. confervoides* f. *gracilis* (Turn.) Grunow 1874, *J. Mus. Godeffroy* 3 (6), 42*; *Fucus confervoides* var. δ *gracilis* Turn. 1809, *Fuci,* tab. 84; *Sphaerococcus capillaris* Kuetz. 1868, *Tab. Phyc.* 18, tab. 74; *Gracilaria confervoides* var. γ *gracilis* (Turn.) Batt. 1902, Suppl. *J. Bot.* 40, 70.

*Standard specimens examined.*—Harv. Alg. Aus. Exsicc. No. 323, Tasmania (Herb. NSW), previously labelled *Gracilaria confervoides.* To this form also belongs Kuetzing's specimen No. 345, labelled *Sphaerococcus* (*Gracilaria*) *capillaris* Kuetz., from Pondicherry, India (Herb. MEL).

Differs from the preceding forms mainly in its fineness (Plate 2, Fig. 1). Thallus rarely exceeding 30 cm. in length, and limited to about 0·35 mm. in diameter. Branching slightly more dichotomous when very young than in the mature f. *confervoides,* but this difference not maintained as the plant ages and enlarges, when lateral branching more characteristic of other forms of this species is developed.

At the base of f. *confervoides,* f. *ecortica,* or f. *tumida* there may be found remains of a condition similar to f. *gracilis* showing that apparently the latter is, in this case, merely a transitional or juvenile growth-form (e.g., Herb. VM, No. 685). As such it would not merit the status of a form. However, under certain habitat conditions the juvenile habit is maintained throughout the life cycle; it is in fact an eco-form and has been found in most parts of Australia. This eco-form seems to characterize areas where greater changes in salinity occur. It extends further up the estuaries than do the other forms, occurring in lagoons and lakes, and in associations near mangroves at river mouths. It occurs frequently on whelks, and is often found in localities where there is much fine mud.

The transverse section of the thallus of f. *gracilis* shows the same range in structure as that shown between f. *confervoides* and f. *ecortica* (as might be expected in a juvenile phase of the species), but as there is no correlation yet discovered between distribution and these changes in structure, it is probably wiser for the present to consider all these plants as belonging to the one form f. *gracilis.* In certain cases (generally in very young plants and more frequently in those from southern areas), the structure shown in transverse sections shows a less distinct junction between cortex and central cells than is usual for *G. confervoides,* while the cell contents may be distinctly dense. Both kinds of sections have been obtained from an individual plant (e.g., Herb. VM, No. 637, from Lake Illawarra, N.S.W.; Plate 2, Fig. 1). Thus within f. *gracilis*

* In this publication Grunow states that *G. confervoides* f. *gracilis* is synonymous with *Sphaerococcus capillaris.* This statement is the basis for some of the present list of synonymy.

there is a transition in the structure shown in a transverse section of the thallus from that characteristic of the Macrocystideae to one nearer that of the Microcystideae. Associated with this variation in the thallus of f. *gracilis* toward the Microcystideae, there is a gradation in the shape of the cystocarp, which sometimes develops a distinct beak (Plate 2, Fig. 1). Both beaked and non-beaked cystocarps may occur on the same branch (e.g., in material from Laurieton, N.S.W.), so that this character, too, must be considered here as merely individual variation. Thus *G. confervoides* f. *gracilis* may show close affinity with a form such as *G. secundata* f. *pseudoflagellifera* or f. *flagellifera*. The specimens of f. *gracilis* from Lake King, Victoria, are very similar to the specimens No. 5 from Low Head, Tasmania, cited in this paper as *G. secundata* f. *pseudoflagellifera*. Perhaps this variation in f. *gracilis* indicates recapitulation of evolutionary stages in ontogeny, or it may be due to there being a certain amount of hybridization between *G. confervoides* and *G. secundata*. It is because of this transition between the species that *G. confervoides* f. *gracilis* has been shown in Diagram 2 as linked to *G. secundata*. J. Agardh (1901) appears to have been aware of this variation in structure of the eco-form (f. *gracilis*) of *G. confervoides*. He describes an English specimen of *G. confervoides* in which the structure of the transverse section of the thallus was normal for the species except in a thin region at the base of the plant. Here, he states, the structure matched that of *Fucus scorpioides* Fl. Dan. (described as similar to that of the Microcystideae). Agardh says further that *Fucus scorpioides* grows under conditions which differ from those which are usual for normal *G. confervoides*, and he records this form, but without form name, as occurring in Australia.

*Localities*

*Queensland.*—Brown's Bay, Flecker, 8/1935 (AHSL). Keppel Bay: (MEL); Kilner, 1874 (MEL). Moreton Bay: Redcliffe, drift, 1/1944 (VM 762); Stradbroke Island, Adam's Beach, on flats, just below L.T.L., 1/1944 (VM 760, 761); Stradbroke Island, Myora, 11/1943 (VM 765); Stradbroke Island, Myora, to One Mile, 1/1944 (VM 763).

Additional localities, C.S.I.R.—Urangan, Sandy Straits (Cowrie Creek), Noosa, Moreton Bay (Caloundra, Deception Bay, Fisherman's Island, Moreton Big Banks).

*New South Wales.*—Laurieton, Queen's Lake Flats, on whelks, 1/1945 (VM 611). Hawkesbury River, Barrenjoey Head, 2/1945 (VM 507). Port Jackson: Fig Tree Bridge, 5/1945 (VM 753); Lane Cove River, Mangrove Swamp, 5/1945 (VM 755); Rose Bay, Lucas, 6/1899 (SYD). Botany Bay: Lucas, 4/1906 (AHSL); George's River Bridge, South Head, *Zostera* flat, 12/1944 (VM 242); Sans Souci, Lucas, 7/1902 (AHSL). Port Hacking, near East Bundeena Head, growing in tufts on rocks, 6/1945 (VM 835). Cabbage Tree Reserve, in lagoon, drift, 3/1945 (VM 650). Lake Illawarra: Kanahooka Point, on rock ledges, 3/1945 (VM 637, 638); near Picnic Island, 3/1945 (VM 651); near Picnic Island, drift, 3/1945 (VM 636).

Additional localities, C.S.I.R.—Chinderah, Tweed, Clarence River (Lawrence), Urunga, Macleay River, Lake Innes, Tuggerah, Port Jackson (Middle Harbour), Greenwell Point, Conjola, Burrill, Durass, Bateman's Bay, Moruya, Tuross, Dalmeny, Narooma, Cuttagee, Wapengo, Bega, Merrimbula.

*Victoria.*—Lake King, Mueller, 2/1855 (MEL, NSW). Port Phillip, Mueller, 15, 9/1852 (MEL).

*Tasmania.*—Georgetown, on stones, rivulet, Harvey 323 (NSW).

*South Australia.*—Encounter Bay, Cleland (AHSL, JBC). Port Adelaide, Mueller, 3/1848 (MEL).

*Western Australia.*—Perth district: Swan River, 11/1942 (VM 759, 764); Swan River, Lower Canning Bridge, 10/1944 (VM 201).

Additional localities, C.S.I.R.—Bunbury Beach.

### 2. Gracilaria lichenoides (L. ex Turn.) Harv.

*Gracilaria lichenoides* (L. ex Turn.) Harv. 1844, *Lond. J. Bot.* 3, 445; *Fucus lichenoides* L. ex Turn. 1809, *Fuci,* tab. 118A (excl. var. & synon.).

On the evidence of only a limited number of herbarium specimens, *Gracilaria lichenoides* can be divided into numerous apparent species. In the field, or with a sufficiently large assemblage of specimens for comparison, these apparent species are found to intergrade, i.e., they lack discontinuities. Since there are many plants intermediate in structure between certain units previously regarded as distinct species, *G. lichenoides* is here regarded as including an extensive range of forms, many of which have been reduced in status from that of species.

Habit tufty; branches with limited growth; plant generally 7–22 cm. high. Thallus usually terete, rarely flattened for the whole length of the branches, frequently green, drying to dark-purple. Plant adhering only moderately to paper on drying. Branching irregular, often dichotomous, and in parts distichous-pinnate, sometimes in part secund. Constrictions at branch-insertion sometimes occurring in var. *constricta,* f. *lichenoides,* and f. *Lemania.* Branch width at base 0·5–2·0 mm., usually 1·5 mm., the width decreasing towards the apices. Cystocarps often flattened, some with slight beaks at the ostiole. Structure of the thallus in transverse section always showing a distinct junction between the large central cells and the small cells at the periphery (Macrocystideae); central cells usually fairly uniform in size, though a certain amount of gradation in size may occur; central cells large, often six across any one diameter, sometimes up to twelve or more near the base of the plant; granular cell contents not conspicuous; superimposed tissue little or none, and if present then only near the base of the plant.

The writer has not recognized the sub-cortical cells whose thick walls show radial striae described as characteristic for the species by Okamura (1929-32, vol. 6, p. 39, plate 27); Okamura's illustrations match f. *Lemania* in habit but not in the structure of the transverse section of the thallus.

The following units may be recognized among Australian specimens of *G. lichenoides:* f. *lichenoides;* f. *taenioides;* f. *complanata;* f. *Lemania;* f. *polyclada;* f. *coronopifolia;* f. *Lucasii;* and var. *constricta.* These units grade imperceptibly into each other, which is why they are regarded as forms, not species. In Diagram 2 is shown the relationship between the different forms of this species to each other and to other species. The softer-textured forms of the species (f. *Lemania,* f. *taenioides,* f. *Lucasii,* f. *polyclada,* and to a less extent var. *constricta*) compress on drying much more than do *f. lichenoides* and f. *coronopifolia.*

As stated above the structure shown in a transverse section of the thallus of *G. lichenoides* may show a certain gradation in the size of the central cells themselves, and so this structure grades toward that of the Microcystideae, some specimens of f. *Lemania* and f. *taenioides* resembling *G. secundata* f. *pseudoflagellifera* and *G. furcellata* f. *ramulosa* respectively. However, the sudden transition from the central cells to the small peripheral cells will distinguish *G. lichenoides* from these species.

*G. lichenoides* is compared with *G. confervoides* and *G. Howensis* under the headings of these species respectively.

*G. lichenoides* occurs from the East Indian to the Pacific Ocean, from India, through the East Indies, to Australia. It is particularly rich in number of forms, and this richness perhaps indicates that active speciation is proceeding at the present time.

Observations on the growth of *G. lichenoides* have shown that it is seasonal, the plants growing to a maximum during the summer, and disappearing, or almost so, during the winter months (June, July, and August); the development of reproductive structures follows the same seasonal cycle. Generally this species occurs on rocks from near the level of low tide downwards, forming horny tufts.

The records under each form name are based on specimens examined by the writer. In addition Harvey (1844) recorded from Georgetown, Tasmania, a plant as "either *G. lichenoides,* or a species very closely resembling it". The specimen to which Harvey referred is, unfortunately, not in Australia, so it is not available to the present writer for study. *G. lichenoides* is not otherwise known to occur in Tasmania. Similarly De Toni and Forti (1923) record *G. lichenoides* from South Australia. These two locality records are indicated with a query mark against *G. lichenoides* f. *lichenoides* in Diagram 1.

*Key to the Forms of* G. lichenoides

1. Plant without numerous close branches.

    2. Branches mainly from the upper portion of the plant.

3. Branches not flattened toward the apices.
   4. Texture coarse. Plant not flattening on drying. Colour pallid .. f. *lichenoides* (page 29).
   4′. Texture soft. Plant flattening on drying. Colour dark. Branching often corymbose .. .. f. *taenioides* (page 30).
3′. Branches flattened toward the apices.
   5. Branches cuneate .. .. f. *polyclada* (page 36).
   5′. Branches flattened-linear in the upper portion of the plant .. f. *complanata* (page 37).
2′. Branching uniformly distributed about the length of the plant.
   6. Plant with constrictions in the branches var. *constricta* (page 38).
   6′. Plant without constrictions in the branches f. *Lemania* (page 32).
1′. Plant with very numerous close branches.
   7. Texture soft .. .. .. .. f. *Lucasii* (page 34).
   7′. Texture tough .. .. .. .. f. *coronopifolia* (page 37).

**G. lichenoides f. lichenoides (L. sensu orig.) stat. nov.**

*Gracilaria lichenoides* (L.) Harv. 1844, *Lond. J. Bot.* 3, 445; J.Ag. 1852, *Sp.* 2, 588; 1876, *Epicr.*, 412; De Toni 1897, *Sylloge Algarum*, 430-1; *Fucus lichenoides* L. ex Turn. 1809, *Fuci*, tab. 118A (excl. var. & synon.).

*Standard specimens examined.*—*G. lichenoides*, Port Denison, Queensland, collected Fitzalan, determined Sonder (Herb. MEL), recorded by Sonder (1871). Also specimen No. 1 (Herb. AHSL) collected F. Perrin and A. H. S. Lucas at Low Island, Queensland, June 1931, identified by W. A. Setchell (letter 1931) as seeming "certainly to be *G. lichenoides*".

Habit tufty, several branches arising from the base of the plant but most branches arising irregularly from above that level, resulting in the upper half of the plant bearing noticeably more branches (Plate 2, Fig. 2). "Stolons" usually developed, thus forming a series of tufted plants. Constrictions frequent at the insertion of a branch.

Many plants of this assemblage show a colourless pallid surface (from which the species name is derived), and do not collapse or adhere to paper on drying. Slight gradations occur, however, in these characters, and relate

this form closely to f. *taenioides*. A sheet in the National Herbarium, Melbourne, shows a range of this kind within the one collection (Algae Muellerianae, Curante J. G. Agardh distributae, from Port Douglas, Queensland). Material from the herbarium of A. H. S. Lucas (some of which has since been distributed to the herbarium of the University of Sydney as duplicates) shows a range uniting these form limits (f. *lichenoides* to f. *taenioides*).

This form is characteristic of warm waters, and in Australia is rarely found south of Queensland.

*Localities*

*Queensland.*—Gulf of Carpentaria: (MEL); Müller, 1868 (MEL). Goode Islands, 1881 (MEL). Thursday Island: (NSW); Palmer, 1883 (MEL). Cape Flattery (Alg.Muell.) (MEL). Point Archer, 9 m. N. of Cooktown, Kelly, summer 1934-5 (AHSL, SYD). Endeavour River: Persich, 1883 (MEL); ad ostia (MEL). Cooktown, 1879 (MEL, NSW). Port Douglas (Alg.Muell.) (MEL). Low Island: Perrin & Lucas, 5/1931 (AHSL); Perrin & Lucas, 6/1931 (NSW, AHSL 1). Dunk Island: Banfield (SYD); Banfield, 7/1909 (BRI 77); Banfield, summer 1913-4 (NSW); Brammo Bay, Banfield, 6/1909 (BRI 25). Townsville, Cleveland Bay, Watt (MEL). Cape Upstart (MEL). Port Denison, Fitzalan (MEL). Port Newry, Mackay, 1/1943 (VM 766). Moreton Bay, Simmonds, 9/1909 (BRI 121).

*New South Wales.*—New South Wales, Austral, Daemel 38 (MEL). Ballina, Henderson (MEL).

**G. lichenoides f. taenioides (J.Ag.) stat. nov.**

*G. taenioides* J.Ag. 1852, *Sp.* 2, 593; 1876, *Epicr.*, 413 (excl. synon.); De Toni 1897, *Sylloge Algarum*, 432-3 (excl. synon.); *Sphaerococcus spinescens* Kuetz. 1868, *Tab. Phyc.* 18, tab. 79, figs. a-b; *Gracilaria spinescens* (Kuetz.) J.Ag. 1876, *Epicr.*, 418; De Toni 1897, *Sylloge Algarum*, 440 (excl. loc. Tas.).

*Standard specimens examined.*—A specimen labelled *G. taenioides* leg. E. Daemel, Sydney, det. A. Grunow, teste J.Ag., ex museo Godeffroy Hamburgensis (now Herb. MEL) is a poor sample, but it is considered as an authentic specimen of *G. taenioides*. A second specimen of this form is No. 2 (Plate 3, Fig. 1) from Low Island, Queensland, May 1931, collected by F. Perrin and A. H. S. Lucas (Herb. AHSL). Setchell (1931 letter) says of this specimen "No. 2 certainly comes very close to, and I think is only a form of, *G. spinescens* Kuetz. It is possibly slightly more regular in its branching ——." Material from Apia, Samoa, now in the herbarium of A. H. S. Lucas, accords with this Low Island material.

Differs from f. *lichenoides* in the plant being more flattened on pressing and drying, in drying purple-cartilaginous, not pallid, and in showing a greater development of dichotomous, trichotomous, and corymbose, rather than irregular,

branching. In these characters it approaches f. *Lucasii,* but differs in being less freely branched. Differs from f. *Lemania* in the branching being mainly from the upper portion of the plant.

Material from the herbarium of A. H. S. Lucas (some of which has since been distributed to the herbarium of the University of Sydney as "duplicates") shows a range in texture and colour uniting the forms f. *lichenoides* (q.v.) and f. *taenioides.* In the National Herbarium, Melbourne, there is a specimen of f. *lichenoides* from Thursday Island (coll. 1883), which shows a small amount of trichotomy, thus f. *lichenoides* approaches f. *taenioides* in this character also.

It seems likely that *G. lichenoides* f. *lichenoides* grades into *G. corymbosa* J.Ag., from the Friendly Islands (= *G. armata* Harvey No. 38, 1855, Friendly Islands ex Herb. AHSL; non *G. armata* J.Ag.).

A specimen, No. 2048, labelled *G. disticha* J.Ag. collected Singapore, and "com. Museum bot. Hamburgense, teste J.Agardh" (Herb. NSW), appears to belong to this form. Another specimen (Herb. MEL) labelled *G. disticha* (det. Reinbold) also from Singapore, appears to be *G. lichenoides* f. *Lemania.* Thus it is likely that the doubtful record of *G. disticha* in New Zealand (Laing 1939) also refers to *G. lichenoides,* a species also doubtfully reported from New Zealand, and which, being well represented in the nearby Australian waters, is considered much more likely to occur there. Laing (1939), however, suggests that *G. disticha* in New Zealand may be a misnomer for *G. secundata,* which certainly is well developed in that country, and which is recorded in the present paper as from Moeraki, the New Zealand location cited for *G. disticha.*

Lucas (1927) recorded *G. taenioides* from Michaelmas Cay, off Cairns, Queensland. This specimen (Herb. AHSL) is a *Hypnea.*

*Localities*

*Queensland.*—Point Archer, 9 m. N. of Cooktown, Kelly, summer 1934/5 (SYD). Endeavour River (Alg. Muell.) (MEL). Low Island: Perrin & Lucas, 5/1931 (AHSL 2, SYD); Perrin & Lucas, 6/1931 (NSW, AHSL, SYD). Dunk Island: Banfield, 7/1909 (BRI 72); Banfield, 10/1909 (BRI 201); Banfield, 10/1910 (BRI 305); Brammo Bay, Banfield, 6/1909 (BRI 37, 47). Noosa Heads: Longman, 9/1913 (AHSL, SYD); drift, 11/1943 (VM 561, 769). Moreton Bay: Bailey, 4/1911 (BRI 333); Redcliffe, drift, 12/1943 (VM 767, 883); Redcliffe, drift, 1/1944 (VM 768, 885).

Additional localities, C.S.I.R.—Moreton Bay (Amity, Margate, Southport).

*New South Wales.*—Sydney, Daemel, ex museo Godeffroy, Hamburgensis (MEL). Port Jackson: Middle Harbour, trawled, 4/1944 (VM 155); Middle Harbour, trawled, 12/1944 (VM 228, 230).

**G. lichenoides f. Lemania (Kuetz.) stat. nov.**

*Sphaerococcus Lemania* Kuetz. 1868, *Tab. Phyc.* 18, 26, tab. 75. *Gracilaria Lemania* (Kuetz.) Sond. 1871, *Die Algen des tropischen Australiens,* 55.

*Standard specimens examined.*—An exotic specimen, *Sphaerococcus Lemania* Kuetz. from New Caledonia, collected by Veillard, determined by Kuetzing, is in the National Herbarium, Melbourne. This plant is evidently the standard reference by means of which Sonder named his Cape York material of *G. Lemania.* Kuetzing's sample is too small to give much indication of the habit of the whole plant. In the same herbarium is the specimen of *G. Lemania,* collected at Cape York by Daemel and identified by Sonder. This appears to be Sonder's *G. Lemania* recorded by him in 1871. This specimen is small (Plate 4, Fig. 2) but it appears to be the form described below.

Differs from f. *taenioides* mainly in the branching being fairly evenly distributed, not predominantly from the upper part of the plant. Gradations between these two forms occur, f. *Lemania* evidently being the southern counterpart of f. *taenioides,* which in turn gives way to f. *lichenoides* further north. When branching is frequent, specimens of f. *Lemania* approach f. *Lucasii* (Plate 4, Fig. 1).

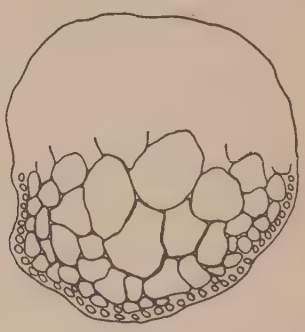

FIG. 3.—Transverse section of the thallus of *G. lichenoides* f. *Lemania.* This section is representative of most forms of this species. Approx. × 40.

A representative transverse section of the thallus of f. *Lemania* is shown in Fig. 3, and a habit study of the plant in Plate 3, Fig. 2.

A number of Australian specimens (Herb. MEL) previously treated merely as *G. lichenoides* (Alg. Muellerianae, Curante J. G. Agardh distributae) are now placed under f. *Lemania.*

Some plants of f. *Lemania* resemble some exotic specimens of *G. compressa* (Ag.) Grev. but may be distinguished by their tufty habit and terete thallus. The records (Sonder in Mueller (1881) and J.Ag. (1901)) of *G. compressa* from Queensland perhaps refer to this form; no named specimen is available to enable me to check these records. The only other locality record I have been able to find of *G. compressa* in Australia is on p. 255 of Meredith (1881), where the species occurs in a " List of algae collected at Orford, east coast of Tasmania,

by the author, and named by Professor C. S. Agardh". In the absence of Meredith's specimen, and with the reassessment of the species of *Gracilaria* since 1881, this record is regarded as doubtful. Bailey (1912) included *G. compressa* in his catalogue of the Queensland plants, but Lucas (1909) did not include it in his list of marine algae of Australia. Weber van Bosse (1928, p. 498) in her distribution lists showed *G. compressa* as absent from Australia. The present writer has not recognized *G. compressa* among the Australian collections of *Gracilaria.*

*Discussion*

Specimens have been examined of *G. compressa* Grev. (Herb. MEL) from Cherbourg and Pozznoli, ex Herbario J. G. Agardh, and from St. Vaal, det. Areschoug. These specimens strongly suggest *G. lichenoides* f. *Lemania.* Actually the least flattened forms of *G. compressa* (Ag.) Grev. seem to intergrade on the one hand with *G. lichenoides* f. *Lemania,* and on the other with *G. confervoides* f. *ecortica* or f. *tumida,* and it seems likely that there is no absolute discontinuity.

Greville (1830) rescinded his earlier decision to regard *G. lichenoides* and *G. compressa* as the same species; however, he did not state wherein they differ.

Okamura (*Icones,* Vol. 5, 1923-8) compared *G. compressa* with *G. confervoides* and found that they differ mainly in that *G. confervoides* shows a degree of secundity of branching, more constriction at the branch insertion, and a greater development of cortex. The present writer has found that all these characters may vary a great deal in a single plant of *G. confervoides.* Okamura states that *G. confervoides* has smaller central cells than has *G. compressa,* but Weber van Bosse (1928) says the opposite.

In Australia, although *G. compressa* is absent, *G. confervoides* and *G. lichenoides* are co-existent, so that the three species cannot be regarded simply as geographic expressions of the one species, though they may be closely allied and at times difficult to distinguish.

Generally *G. compressa* seems distinguishable from the other two species by the fact that at least portion of the fronds is flattened. Sjostedt (1926) also emphasizes the conspicuous development of fragile epidermal hairs in *G. compressa,* and Harvey (1846-1851, plate 205) stresses its greater succulence, softness, and more brittle nature as compared with *G. confervoides.*

*Localities*

*Queensland.*—Cape York, Daemel (MEL). Bowen, Rainford, 3/1928 (AHSL). Port Denison: (Alg. Muell.) (MEL); 1871 (MEL). Sandy Straits, near Maryborough: Cowrie Creek, Sandy Flats, 8/1943 (VM 151); Tin Can Bay, flats, 8/1943 (VM 786). Burnett River, entrance, Keys 74, 1888 (MEL). Moreton Bay: Fisherman's Island, flats, 2/1944 (VM 776); Moreton Big Banks, flats, 12/1943 (VM 682, 686); Moreton Island, drift, 5/1943 (VM 785); Margate, drift, 12/1943

(VM 772); Redcliffe, Lucas (SYD); Redcliffe, drift, 3/1943 (VM 771); Redcliffe, drift, 12/1943 (VM 770); Sandgate, Lucas, 12/1913 (AHSL); Scarborough, on beach cast up by heavy seas, Blake 5069, 1/1934 (BRI); Southport, near Biggerah Creek, trawled, 4/1943 (VM 773); Southport, Labrador, trawled, 2/1943 (VM 774); Stradbroke Island, Amity Beach, drift, 12/1943 (VM 132); Stradbroke Island, Amity Sand Flats, 12/1943 (VM 620); Stradbroke Island, Myora to Amity, on rocks, 1/1944 (VM 787); Stradbroke Island, Swan Bay, 3/1945 (VM 593).

Additional localities, C.S.I.R.—Mary River Mouth, Moreton Bay (Caloundra).

*New South Wales.*—New South Wales, Collie (MEL). Port Stephens (Alg. Muell.) (MEL). Lake Macquarie, Lucas, 1/1918 (AHSL, SYD). Hawkesbury River, Barrenjoey Head, under rock ledge, 2/1945 (VM 506). Sydney district, Lucas (AHSL, SYD). Port Jackson: (Alg. Muell.) (MEL); Ramsay (Alg. Muell.) (MEL); Ramsay (MEL, NSW); Ramsay, 15, 1882 (MEL); Ramsay, 1883 (MEL). Botany Bay: Lucas (AHSL); Lucas, 6/1903 (AHSL); Lucas, 4/1906 (NSW, AHSL 4); Lucas, 6/1906 (AHSL, SYD); Lucas, 1/1912 (NSW, AHSL); Lucas, 5/1930 (AHSL); trawled, 4/1943 (VM 775); George's River Bridge, South Head, on oyster, 3/1945 (VM 543); George's River Bridge, South Head, 3/1945 (VM 541, 542); Sans Souci, Lucas, 6/1898 (NSW); Towra, drift, 3/1944 (VM 298, 300). Port Hacking, near C.S.I.R. buildings, 8/1944 (VM 103, 104, 105).

Additional localities, C.S.I.R.—Port Stephens (Nelson's Bay), Hawkesbury River (Woy Woy), Jervis Bay, Wagonga, Narooma.

**G. lichenoides f. Lucasii (A. & E. S. Gepp) stat. nov.**

*G. Lucasii* A. & E. S. Gepp 1906, *J. Bot.* 44, 256; De Toni 1924, *Sylloge Algarum,* 252-3.

*Standard specimen examined.*—An authentic specimen of *G. Lucasii* A. & E. S. Gepp from type locality, date and collector, is in the National Herbarium of New South Wales.

Differs from other forms of the species (except f. *coronopifolia*) in the presence of numerous short branches, and from f. *coronopifolia* in being much softer and more compressed on drying.

The difference between f. *coronopifolia* and f. *Lucasii* parallels that between f. *lichenoides* and f. *taenioides,* and f. *coronopifolia* bears the same relationship geographically to f. *Lucasii* as does f. *lichenoides* to f. *taenioides,* occurring as the more northern counterpart. Specimens of f. *Lucasii* from less sheltered places (e.g. Lord Howe Island) are somewhat firmer in texture than the haptotype, which is from a sheltered cove in Sydney Harbour; these specimens thus show gradations between f. *Lucasii* and f. *coronopifolia.*

Within the form *Lucasii* (a representative example of which is shown on Plate 5, Fig. 1), there is variation in the degree of flattening at the apices of the branches, so that there is a smooth transition from f. *Lucasii* where apices may be flattened, to f. *polyclada* where axes are flattened. The closeness of branching in f. *Lucasii* also varies considerably; when the branching is less crowded, f. *Lucasii* grades smoothly toward f. *Lemania* (e.g. material from Botany Bay, Plate 4, Fig. 1); where these two forms are growing near each other f. *Lucasii* occurs in those areas which receive less wave action during emergence at low tide.

In the original description of *G. Lucasii,* A. & E. S. Gepp (1906) state " Cystocarpia et tetrasporangia ignota." Both have been found since and agree with those of *G. lichenoides.*

Referring to the species *G. Lucasii,* De Toni (1924) says " *Grac. lichenoidi* quoad structuram haec species hoc affinis videtur, forsan cum ejesden var. *corniculata* Sond.* comperanda." On the other hand Setchell (letter 1931) says *G. Lucasii* " has no resemblance whatever to *G. lichenoides,*" but I think this statement must refer to extreme forms judged only on habit. A. & E. S. Gepp (1906) in describing *G. Lucasii* state " in structure (it) is closely related to *G. lichenoides* ——." They state that their species differs from *G. lichenoides* in lacking " the usneoid habit " of the latter. Forma *Lucasii* also differs from f. *lichenoides* in being much more closely branched, especially towards the apices, and in being of softer texture, so that it compresses more on drying. It also generally dries darker in colour and more often the secondary branching of any one primary branch is in one plane.

Forma *Lucasii* is the form of *G. lichenoides* which approaches most closely to *G. arcuata* Zan. (illustrated in Okamura's *Icones* 1929-32, Vol. 6, p. 40, plate 272). However, the latter species differs from *G. lichenoides* in that the branches are characteristically curved, and more frequently secund in arrangement, and further, the plant is much larger, fleshier, and wider (width 1·5–2·5 mm.) and dries rugose. The greater degree of branching (in *G. lichenoides*) shown by f. *Lucasii* is parallelled in *G. arcuata* by var. *Snackeyi* W. v. B.

*G. lichenoides* f. *Lucasii,* in the absence of fertile material, may resemble in habit a species of *Hypnea.* A rapid method for distinguishing these genera is based upon the presence of very much more acute apices in *Hypnea.*

*Localities*

*Queensland.*—Bowen, Rainford, 1930 (AHSL). Burnett River, entrance, Keys 36, 1888 (MEL). Moreton Bay: White, 1/1912 (BRI 385); Bribie Island, 10/1944 (VM 779); Fairway Beacon, 8/1945 (VM 900); Margate, drift, 12/1943 (VM 884); Sandgate, White, 12/1911 (BRI 370); Redcliffe,

* Now *G. lichenoides* f. *coronopifolia.*

Lucas (AHSL); Redcliffe, drift, 3/1943 (VM 777); Redcliffe, drift, 1/1944 (VM 160); Stradbroke Island, Amity, 11/1943 (VM 781); Stradbroke Island, Dunwich to One Mile, with mussels, 1/1944 (VM 886); Stradbroke Island, Myora to Amity, on rocks, 1/1944 (VM 788); Woody Point, Lucas, 12/1913 (NSW, SYD, AHSL).

Additional localities, C.S.I.R.—Moreton Bay (Fisherman's Island).

*New South Wales.*—Port Stephens: Lucas, 3/1913 (NSW, AHSL, SYD); Nelson's Bay, Carey, 1/1931 (SYD). Port Jackson: Lucas (MEL, AHSL, SYD); Lucas, 7/1901 (NSW); Double Bay, trawled, 7/1943 (VM 780; near Double Bay, trawled, 7/1944 (VM 782); Elizabeth Bay, Lucas (AHSL, SYD); Farm Cove, Lucas, 7/1901 (NSW); Farm Cove, Lucas, 6/1909 (AHSL, SYD); Farm Cove, Lucas, 2/1913 (AHSL, SYD); Farm Cove, Lucas, 1/1914 (MEL, NSW, AHSL, SYD); Farm Cove, Lucas, 3/1914 (AHSL, SYD); Farm Cove, Lucas, 4/1914 (AHSL); Farm Cove, Lucas, 1/1921 (MEL, AHSL, SYD); Farm Cove, Lucas, 5/1929 (AHSL, SYD); Farm Cove, Lucas, 3/1930 (AHSL); Farm Cove, trawled, 7/1944 (VM 778); Middle Harbour, Lucas, 5/1906 (AHSL, SYD); Mosman, Lucas, 6/1899 (AHSL); Mosman, Lucas, 12/1899 (AHSL); Watson's Bay, Evans, 5/1920 (AHSL, SYD); Wooloomooloo Bay, Lucas, 1/1911 (AHSL, SYD); Wooloomooloo Bay, Lucas, 6/1915 (NSW, AHSL, SYD); Wooloomooloo Bay, Lucas, 1/1919 (AHSL, SYD); Wooloomooloo Bay, Lucas, 11/1931 (AHSL). Botany Bay: Lucas, 1/1905 (AHSL); Lucas, 2/1905 (AHSL, SYD); Lucas, 6/1909 (NSW); Lucas, 12/1912 (NSW); Lucas, 5/1930 (SYD); George's River Bridge, South Head, on molluscs, 12/1944 (VM 250, 251); George's River Bridge, South Head, 3/1945 (VM 540); Sandringham, Lucas, 1/1904 (NSW); Sandringham, Lucas, 12/1930 (AHSL).

Additional localities, C.S.I.R.—Brisbane Waters.

*Lord Howe Island.*—Lord Howe Island: Perrin & Lucas, 6/1933 (SYD); North Reef, Dun & Hedley, 9/1908 (NSW).

**G. lichenoides f. polyclada (Sond.) stat. nov.**

*G. polyclada* Sond. 1871, *Die Algen des tropischen Australiens*, 56; De Toni 1897, *Sylloge Algarum*, 455-6.

*Standard specimen examined.*—Only one specimen (Plate 5, Fig. 2) of this form is available to the writer, viz., Sonder's type specimen from Port Denison, collected by Fitzalan 1868, and now in National Herbarium, Melbourne.

Differs from other forms of *G. lichenoides* in the cuneate branches, the thallus wider and flatter beneath each division, and the whole branching system at length palmatifid.

Branching is rather more frequent than in f. *lichenoides* and f. *taenioides*, but less so than in f. *coronopifolia* or f. *Lucasii*. Since the texture in f. *polyclada*

is soft and the thallus compresses on drying, this form is more closely allied to f. *taenioides* or f. *Lucasii* (q.v.); thus f. *polyclada* is shown in Diagram 2 as linked to these two forms.

The resemblances between f. *polyclada* and f. *complanata* are discussed under the latter name.

*Localities*

*Queensland.*—Port Denison, Fitzalan, 1868 (MEL).

**G. lichenoides f. coronopifolia (J.Ag.) stat. nov.**

*G. coronopifolia* J.Ag. 1852, *Sp.* 2, 592-3; 1876, *Epicr.*, 414-5; De Toni 1897, *Sylloge Algarum,* 434-5; *G. lichenoides* var. *corniculata* Sond. 1871, *Die Algen des tropischen Australiens,* 55; De Toni 1897, *Sylloge Algarum,* 431.

*Standard specimens examined.*—*G. coronopifolia* J.Ag. from "Woahoo, Ins. Sandwicens," Capt. Wilkes, labelled in Sonder's handwriting, in the Exotic Algae of the National Herbarium, Melbourne, appears to be part of the type material of this form (Plate 6, Fig. 2). On one label of this collection of plants Sonder has written "var. *Grac. lichenoides?*" Plate 6, Fig. 1 illustrates Australian material which matches this collection. The earliest record of this form for Australia (Plate 6, Fig. 3) is a sheet labelled *G. lichenoides* var. *corniculata* Sond. Port Denison, coll. Fitzalan (Herb. MEL). The specimen is labelled in Sonder's handwriting as collected by Fitzalan, together with a reference to *Die Algen des tropischen Australiens*; this is considered as Sonder's type material, although in the latter publication the collector is named as Kilner.

Plant tufty and producing numerous short branches. Similar to f. *Lucasii,* but differing mainly in its firmer texture and in being less compressed on drying. Similar to f. *lichenoides* in texture, but differing in the presence of numerous short branches.

The range of f. *coronopifolia* extends to Formosa, the Marianna Islands and the Islands of Ponape (Yamada 1938).

*Localities*

*Queensland.*—Thursday Island, Vernon, 10/1927 (AHSL). Lindeman Island, Ward, Aug. Sep. 1935 (AHSL). Port Denison: 1868 (MEL); Fitzalan (MEL). Moreton Bay, Redcliffe, drift, 1/1944 (VM 784).

*Norfolk Island.*—Robinson, 4/1904 (NSW).

**G. lichenoides f. complanata forma nov.**

Affinis f. *polycladae,* sed frondibus linearis-complanatis (non cuneatis), saepe apicibus obtusioribus, differt.

Plant tufty, of limited growth, about 10 cm. long, attached by a disk. Thallus firm, not cartilaginous, much collapsed on drying, flattened (even after prolonged re-soaking), not adhering to paper. Branching in parts dichotomous, often emerging from the edges of an axis, the plant becoming somewhat distichous. Branches not constricted at their insertion, the axis rarely with a constriction. Apices with rounded points. Base of the plant less flattened

than the upper portions, where the width may be 2 mm. Axis in transverse section (Fig. 4) showing rather numerous clear central cells of fairly uniform size, clearly distinguishable from the small cells of the thin peripheral zone; cell walls thin; a few rows of superimposed tissue of secondary cortex developed near the base of plant. Cystocarps present on both plane and edge surfaces of the thallus. Plate 7, Fig. 1, shows the habit of this form, and Fig. 4 shows the structure of the thallus in transverse section.

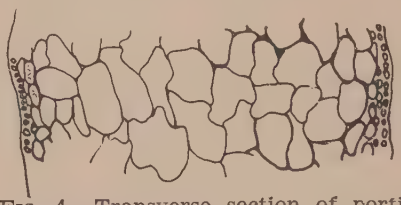

FIG. 4.—Transverse section of portion of the flattened thallus of *G. lichenoides* f. *complanata*. Approx. × 40.

This form is allied to *G. lichenoides* by its tufty habit and the similarity of the thallus as seen in transverse sections. It is, unfortunately, based upon a single herbarium sheet of four portions (the type being the only complete plant) of algae collected at Point Archer, nine miles from Cooktown, North Queensland, by Mrs. Kelly in summer 1934-5, and now in the herbarium of A. H. S. Lucas. The specimen was identified by A. H. S. Lucas as *G. taenioides* J.Ag.

Forma *complanata* differs from other forms of this species in that it is decidedly flattened and the apices are more rounded. In habit it approaches nearest to f. *polyclada,* which has branches widening upward (Plate 5, Fig. 2), but differs in that it is much more uniformly flattened, and the apices may be more obtuse. Forma *taenioides,* when branching is dichotomous to trichotomous and the plant has flattened on drying, also may appear similar to f. *complanata;* however, the thallus differs in being terete when soaked.

*G. lichenoides* f. *complanata* and *G. Textorii* are both flattened and dichotomous, but the former is of more compact habit and the structure of the thallus in transverse section readily distinguishes them, *G. Textorii* having many fewer cells across one diameter.

*Localities*

*Queensland.*—Point Archer, 9 m. N. of Cooktown, Kelly, summer 1934-5 (AHSL).

**G. lichenoides var. constricta Zan.**

*G. lichenoides* var. *constricta* Zan. 1872, *Mem. R. Ist. Veneto* 17, 142; De Toni 1897, *Sylloge Algarum,* 431.

*Standard specimen examined.*—Identification of the Australian material has been based on a plant from the National Herbarium, Melbourne, labelled No. 35, *G. lichenoides* var. *constricta* Zan., Sarawak, L. Beccari, ex. Herb. Zanardini. This is believed to be a portion of the type material of the variety.

Similar to f. *Lemania,* but differing in the occasional presence of constrictions in the axes themselves (reminiscent of those found in the genus *Corallopsis*); constrictions frequent at the insertion of the branches.

The plant surface may be pallid, as in f. *lichenoides,* and so Diagram 2 shows var. *constricta* as grading towards both f. *lichenoides* and f. *Lemania.*

This variety (Plate 7, Fig. 2) is scantily represented in the material I have examined.

*Localities*

*Queensland.*—Dunk Island: Banfield (AHSL); Banfield, 10/1910 (BRI 307); Banfield, summer 1913-4 (NSW). Bowen, Stone Island, Rainford, 10/1926 (AHSL). Port Newry, Mackay, 1/1943 (VM 789).

### 3. Gracilaria Howensis Lucas

*Gracilaria Howensis* Lucas 1935, *Proc. Linn. Soc. N.S.W.* 60, 220-1.

A. H. S. Lucas (1935), in his description of a new species of *Gracilaria* from Lord Howe Island, does not give a specimen number, or state when or by whom the type specimen was collected, or where it is stored. During my examination of all the available specimens of *Gracilaria* in Australian herbaria and University collections, I have found only three sheets of a *Gracilaria* from Lord Howe Island, other than the distinctive *G. secundata* f. *secundata.* None of these had been designated as type.

In the herbarium of the University of Sydney, in a box of so-called duplicates distributed from the herbarium of A. H. S. Lucas, is a plant collected at Lord Howe Island by F. Perrin and A. H. S. Lucas, June 1933, on which is printed in pencil (not Lucas' writing) the name *G. Howensis* Lucas. This plant does not, in my opinion, fit the description given by Lucas; it is in fact *G. lichenoides* f. *Lucasii.*

In the National Herbarium of New South Wales is a plant (located with the species of *Gracilaria*) from North Reef, Lord Howe Island, collected by Dun and Hedley, September 1908. It also is *G. lichenoides* f. *Lucasii.*

In the National Herbarium of New South Wales, where Lucas worked for many years, is an unlabelled *Gracilaria* plant collected at Lord Howe Island by J. H. Maiden, March 1898. This plant was located with a large number of other plants from Lord Howe Island, and this collection is likely to have been the material from which Lucas compiled his "Algae of Lord Howe Island", in which the original description of *G. Howensis* appears (1935). This plant, in my opinion, should be considered the type of *G. Howensis* Lucas. It is illustrated in Plate 8, Fig. 1. The fact that this specimen was not so labelled by Lucas himself cannot be held to invalidate its being considered the type, because in at least one other case, viz., that of *Gelidium Maidenii* Lucas, listed and described by Lucas in the same paper, type material was also left unlabelled in the National Herbarium of New South Wales.

It is likely that Lucas drew up his description of *G. Howensis* from more than one specimen, since none of the specimens agree absolutely with his description. The one selected by me agrees in all respects except in not adhering to paper on drying, whereas Lucas stated that it did.

Plant to 8 cm. high, 2 mm. wide; thallus terete, although flattened on drying, without constrictions at the branch insertions. Branching irregularly dichotomous.

Of the Australian species of *Gracilaria* this species is nearest to *G. lichenoides,* since the habit is tufty and the frond terete, and since the structure of the thallus in transverse section shows a sudden junction between the outer and central cells (Macrocystideae). *G. Howensis* differs, however, in being larger and more succulent, in its greater development of cortex, in the thicker walls of the central cells, and in the contents of the outer cells of the cortex being more granular than is usual in *G. lichenoides.* Portion of a transverse section of the thallus is illustrated in Fig. 5.

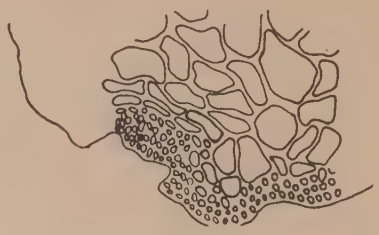

FIG. 5.—Portion of the transverse section of the thallus of *G. Howensis.* Approx. × 40.

Since the branching is mainly from the upper portion of the plant, and the plant compresses on drying, Diagram 2 shows *G. Howensis* linked to *G. lichenoides* f. *taenioides.*

In his description Lucas mentioned the similarity of his new species to *G. dumosa* Harv. from the Friendly Isles (= *G. arcuata* Zan. according to Boergesen (1934)). This similarity is marked, the most obvious difference being that Harvey's dried plant adheres to paper while *G. Howensis* does not. Further, *G. Howensis* is more cartilaginous, with branches more frequent near the top of the plant, and less arcuate or curved. It is likely that these two species should be united, but owing to the lack of adequate numbers of specimens for comparison, I have kept them distinct for the present.

*Localities*

*Lord Howe Island.*—Lord Howe Island, Maiden, 3/1898 (NSW).

### 4. Gracilaria Textorii (Suring.) De Toni

*Gracilaria Textorii* (Suring.) De Toni 1895, *Mem. R. Ist. Veneto* 25 (5), 27, n. 52; 1897, *Sylloge Algarum* 449; 1924, *Sylloge Algarum*, 266-7; *Sphaerococcus Textorii* Suring. 1867, *Ann. Bot. Mus. Lugduno-Batavi;* 1868, *Hedwigia* 7, 56; 1870, *Herausg. Hollandischen Gesell. Wiss. Harlem*, 36, tab. 23; 1870, *Hedwigia* 9, 135; (=*Rhodymenia Textorii* Suring. loci. cit.).

Very variable in form, a range of shapes occurring sometimes in the fronds of a single plant (Plate 9, Fig. 1). Plant almost invariably flattened; up to 30 cm. in length, up to 1 cm. in width, half-tufty. Branching divaricate, predominantly dichotomous, with large proliferations (branches) developed from the edges of the flattened thallus, the apices pointed. Transverse section of thallus (Fig. 6) showing a clear junction between the large central cells and the small cells of the periphery (Macrocystideae), with little or no cortex; central cells large with fairly clear contents, often three central cells occurring across one diameter (up to six at the base), and where branch proliferations develop the old large central cells packed with numerous new smaller cells; secondary cortex sometimes developed, but usually limited to 2–3 layers. Colour varying from green to rose-red. Plant adhering indifferently to paper on drying, crisp and breaking easily when fresh. Cystocarps rather flattened and occurring on any surface.

Fig. 6.—Portion of the transverse section of the thallus of *G. Textorii* f. *tenuis*. The few cells across one diameter is characteristic of this species. Approx. × 40.

*G. Textorii* is distinguished from most Australian species of the genus by its flattened thallus (f. *tenuis* may occasionally be terete, in which case a transverse section of the thallus is needed for its recognition). *G. pannosa* is also flattened, but develops a fringe of tiny proliferous growths which are quite unlike the more massive tissue proliferating from *G. Textorii*.

*G. Textorii* is known from Japan where is was first described, and from Java, recorded by Weber van Bosse (1928).

In Australia this species is largely seasonal, being almost absent during the winter months of June, July, August, and September. Reproductive structures are most frequently produced in the summer months of December, January, February.

This species has usually been obtained by trawling in estuarine waters, when it often comes to the surface attached to various shells. In Botany Bay, however, I have collected it at low tide level; it was then growing attached to oyster shells.

*Key to the Forms of* G. Textorii

1. Plant obviously flattened and rather tufted .. .. f. *Textorii* (page 43).

1′. Plant not obviously flattened, rather finer and less tufted f. *tenuis* (page 43).

*Discussion*

The Australian material of *G. Textorii* resembles in many ways, and may possibly be identical with, the alga *G. foliifera* (Forsk.) Borgs., among whose synonyms Boergesen (1933, p. 124) lists *G. lacinulata* (Vahl) Howe, and also *G. multipartita* (Clem.) J.Ag. De Toni (1897, p. 449) also says of *G. Textorii* " Affinis videtur *Gracilariae multipartitae* (Clem.) J.Ag." However, specimens labelled *G. multipartita* (Clem.) Harv. from England (Herb. NSW and Herb. MEL) show in transverse sections of the thallus rather more central cells across the diameter (6–7) than are generally found in Australian specimens of *G. Textorii.*

To this complex also probably belongs *G. polycarpa* (Harv.) J.Ag., recorded from Australia and New Zealand by J. Agardh (1901), and doubtfully from New Zealand by Laing (1939). Mazzo (1907, p. 2) considered *G. polycarpa* J.Ag. as " f. della *G. multipartita* Harv. sedis ".

These species are similar in that they are all flattened, with branching both dichotomous and proliferous from the margins. It seems likely that they represent geographic expressions of the one superspecies (sensu Mayr 1942). Support is given to this suggestion by the fact that the plants of this complex from India have a " thin thallus " (Boergesen 1933), and so, in this respect, would seem allied to the Australian material described in the present paper; on the other hand European and American specimens have a larger number of cell layers across the transverse section of the thallus, and come from areas geographically more distant. However, the idea of a superspecies with geographically isolated species-units is opposed by the following facts. *G. Textorii* occurs in Japan, and *G. lacinulata* along the China coast (Howe 1924 and Tilden 1929). Howe also states that *G. lacinulata* of China appears " to be identical with " the species as it occurs on the Atlantic coast. Similarly *G. lacinulata* is recorded from New Guinea, and *G. Textorii* from Java (Weber van Bosse 1928). These statements suggest that the complex either consists of a number of biologically isolated, apparently similar species, or is of the nature of a very widely distributed and variable species.

In the absence of type and other material I am not in a position to carry this investigation further at present.

*G. multipartita* var. *angustifolia* (specimen from Herb. MEL exotic algae, labelled from Sud. Carolina leg. Michlfeld) is superficially similar to *G. Textorii* f. *tenuis,* both being much narrower than other forms of their species. However, in transverse section the American plant again shows more central cells (5-6 per diameter) than does the Australian plant.

**G. Textorii f. Textorii (Suring. sensu orig.) stat. nov.**

*G. Textorii* (Suring.) De Toni 1895, *Mem. R. Ist. Veneto* 25 (5), 27, n. 52; 1897, *Sylloge Algarum*, 449; 1924, *Sylloge Algarum*, 266-7; A. & E. S. Gepp 1906, *J. Bot.* 44, 256; Okamura 1901, *Illus. Mar. Alg. of Japan*, V, tab. 23; *Sphaerococcus Textorii* Suring. 1867, *Ann. Bot. Mus. Lugduno-Batavi;* 1868, *Hedwigia* 7, 56; 1870, *Herausg. Hollandischen Gesell. Wiss. Harlem*, 36, tab. 23; 1870, *Hedwigia* 9, 135; (=*Rhodymenia Textorii* Suring. loci. cit.).

*Standard specimens examined.*—Specimens from Botany Bay, N.S.W., No. 11 *et al.* collected by A. H. S. Lucas, April 1900, also February 1905 (Herb. NSW); apparent duplicates of these collections were identified as *G. Textorii* by A. & E. S. Gepp (1906).

This form (Plate 8, Fig. 2) is that normally encountered in Australian waters. It is always obviously flattened, though exhibiting a range of branch widths and shapes, as shown in Plate 8, Fig. 2, and Plate 9, Fig. 1.

*Localities*

*Queensland.*—Moreton Bay: Fisherman's Island Flats, 4/1943 (VM 792); Fisherman's Island, 12/1943 (VM 795); Margate, drift, 12/1943 (VM 793); Redcliffe, Lucas (SYD); Redcliffe, Lucas 53 (AHSL); Redcliffe, drift, 5/1943 (VM 145); Redcliffe, drift, 11/1943 (VM 794); Stradbroke Island, Amity Beach, drift, 12/1943 (VM 130, 131).

Additional localities, C.S.I.R.—Sandy Straits (near Maryborough), Moreton Bay (Deception Bay).

*New South Wales.*—Hawkesbury River, Woy Woy, trawled, 2/1943 (VM 791). Botany Bay: Lucas (NSW); Lucas, 4/1900 (NSW 11 *et al.*, AHSL); Lucas, 1/1905 (NSW, AHSL, SYD); Lucas, 2/1905 (MEL, NSW, AHSL, SYD); Lucas, 4/1906 (NSW); Lucas, 6/1906 (AHSL); Lucas, 6/1909 (NSW); Lucas, 1/1912 (NSW, AHSL); Lucas, 5/1930 (AHSL); off boom, trawled, 12/1944 (VM 888); George's River Bridge, South Head, 3/1945 (VM 535, 536); Sandringham, Lucas, 1/1904 (NSW, AHSL, SYD); Taren Point, on winkle, 3/1945 (VM 545); Towra, drift, 3/1944 (VM 299); Weeny Bay, 2/1945 (VM 887).

**G. Textorii f. tenuis forma nov.**

Affinis f. *Textorii*, sed frondibus angustioribus, raro teretiusculis, et habitu minus caespituloso, differt.

Differs from f. *Textorii* only in the narrower thallus (rarely even terete) and in the habit less tufty or limited in growth. As yet found only in Moreton Bay, Queensland.

The form type is No. 796 in my herbarium; this specimen is illustrated in Plate 9, Fig. 2.

Forma *tenuis* may at times resemble *G. confervoides* f. *tumida;* under the latter species the two are compared.

*Localities*

*Queensland.*—Moreton Bay: Canaipa Passage, trawled, 3/1945 (VM 575, 585); near Halloran Point, 3/1945 (VM 711); Point Halloran, 8/1945 (VM 893); Lamb Island, trawled, 5/1943 (VM 147, 796); Stradbroke Island, Swan Bay, 3/1945 (VM 594); Victoria Point, 8/1945 (VM 891).

Additional localities, C.S.I.R.—Moreton Bay (Fisherman's Island, Redcliffe).

### 5. Gracilaria pannosa (Harv.) J.Ag.

*Gracilaria pannosa* (Harv.) J.Ag. 1884, *Lund. Univ. Arrsk.* 21, 62; De Toni 1897, *Sylloge Algarum,* 450; *Calliblepharis pannosa* Harv. 1855, *Trans. Roy. Irish Acad.* 22, 550; J.Ag. 1876, *Epicr.,* 434; *Calliblepharis Preissiana* Harv. 1858-63, *Phyc. Aust.,* tab. 106 (excl. synon.).

*Standard specimen examined.*—Harv. Alg. Aus. Exsicc. No. 302, Western Australia (Herb. NSW), previously labelled *Calliblepharis Preissiana.* This presumably represents Harvey's later concept of the species.

Thallus flattened, 7–10 cm. long, approximately 0·2 mm. wide, dull-red to purple (*fide* Harvey), not adhering to paper on drying. Characteristic proliferations numerous from the edges of the thallus (Plate 10, Fig. 1). Branching irregular-distichous and sometimes dichotomous. Transverse sections of thallus showing a variable amount of cortex, but always with a sharp junction between the cortex and the central tissue (Macrocystideae).

The habit of this species, with its characteristic proliferations, sufficiently distinguishes it from any other Australian species of *Gracilaria.*

Of the exotic algae I have seen, this species resembles most in appearance *G. cervicornis* (Turn.) J.Ag. from Pernambuco (Herb. MEL), but differs from it in showing a sudden transition from cortex to central tissue in transverse section of the thallus.

According to De Toni (1924) *G. pannosa* is not known outside Australia. The only specimens of it available are from the south of Western Australia, and as yet insufficient material has been collected to provide adequate information regarding its ecology or growth throughout the year.

This species was misdetermined as *Rhodymenia Preissiana* Sond. by J. Agardh (1852, p. 622).

*Localities*

*Western Australia.*—Champion Bay (Alg. Muell.) (MEL). Fremantle, Harvey, 302 (NSW). Geographe Bay (Alg. Muell.) (MEL). King George's Sound, Harvey 302 (NSW).

### 6. Gracilaria canaliculata (Kuetz.) Sond.

*Gracilaria canaliculata* (Kuetz.) Sond. 1871, *Die Algen des tropischen Australiens*, 56; De Toni 1897, *Sylloge Algarum*, 455; *Sphaerococcus canaliculatus* Kuetz. 1868, *Tab. Phyc.* 18, 29, tab. 82, figs. d-e; *Gracilaria ? obtusa* (Grev. ex Kuetz.) De Toni 1897, *Sylloge Algarum*, 443; *Gigartina obtusa* Grev. ex J.Ag. 1852, *Sp.* 2, 590; J.Ag. 1876, *Epicr.*, 426 (nomen); *Sphaerococcus obtusus* Kuetz. 1868, *Tab. Phyc.* 19, 8, tab. 21, figs. a-d.

*Standard specimen examined.*—Of Australian material of this species I have seen only Sonder's specimen of *G. canaliculata* from Cape York, collected by Daemel (Herb. MEL). The whole of this material is illustrated in Plate 10, Fig. 2.

Plant 15—18 cm. long, 2-3 mm., sometimes up to 6 mm., wide. Thallus hard, flat, and a dark colour on drying, not adhering to paper, remaining flat even after prolonged soaking, bearing papillose proliferations at least when dry. Branching irregular and from the edges of the thallus, some but not all of the branches being constricted at their insertion. Structure of the thallus as shown in a transverse section (Fig. 7), consisting of outer layers of small cells containing granular contents, grading to clear and thinner-walled central cells (the species thus being nearer to the Microcystideae than the Macrocystideae, but not agreeing closely with the structure of any of other Australian species of *Gracilaria*).

FIG. 7.—Portion of the transverse section of the thallus of *G. canaliculata*. In this section secondary cortex is shown. Approx. × 40.

This species differs from all other Australian species of *Gracilaria* in its papillose proliferations on the thallus (Plate 10, Fig. 2), and in having coarse, rounded, obtuse apices. Sonder's specimen is large and coarse and suggestive of a species of *Curdiea*.

Weber van Bosse (1928, p. 436) concluded that *G. canaliculata* is a synonym of *G. obtusa*. The Australian specimen here described is very much larger, coarser, more rugose and flattened than Harvey's Exsicc. No. 30 *G. obtusa* Grev., from Ceylon (Herb. MEL); further, although the structure of some parts of the thalli of these two specimens as seen in transverse section do match, many sections from the Ceylon plant show a structure rather closer to that of the Macrocystideae, i.e., they show very little gradation in size from the peripheral cells to the central tissue. The Australian specimen thus appears to be at least a different form from the Ceylon material, but on such a small, single sample it is considered wiser merely to accept the conclusion of Weber van Bosse (loc. cit.) for the time being.

The affinities of the Australian specimen described above must remain in some doubt until we have some additional collections of it.

This species, accepting Weber van Bosse's 1928 interpretation of it, ranges from Australia and New Caledonia to Ceylon.

*Localities*

*Queensland.*—Cape York, Daemel (MEL).

### 7. Gracilaria secundata Harv.

*Gracilaria secundata* Harv. 1863, *Phyc. Aust.*, No. 432 (non S. & G. 1937).

*Standard specimens examined.*—I have examined Harvey's plants of *G. secundata,* No. 325, Aus. Alg. Exsicc. collected Newcastle, New South Wales (from both Herb. MEL and Herb. NSW). Harvey's type locality for this species was recorded as Kiama, New South Wales, No. 325, but I have not seen his plant from this locality. Further, the writer, though finding the species at Newcastle, has so far been unable to find it growing at Kiama.

A photograph of Harvey's plant No. 325 is shown in Plate 11, Fig. 1. The variations about this form are distressingly numerous. At different times I have regarded members of this species as being relatively independent species, but the wider the range of material I have examined, the wider has been my interpretation of *G. secundata.* The species, as now considered, approaches a superspecies (sensu Mayr 1942) but is not yet this, since no discontinuities have been found.

Habit tufty to half-tufty, with cylindrical to elliptical axes. Branching often secund, sometimes distichous or corymbose, and in parts irregular, the branches sometimes tapering at their insertions in a manner reminiscent of *G. Harveyana,* the apices generally pointed. Thallus dark red or purple on drying, sometimes light brown when growing, not adhering to paper when dry, usually cartilaginous, usually moderately uniform in width in any individual specimen, but varying within the species, attached by a disc hold-fast rather larger than in most species of the genus. Cystocarps varying in size and shape on a single plant; often beaked particularly in f. *pseudoflagellifera.*

This species belongs to the Microcystideae group of species, as, in transverse section, the thallus shows no distinct junction between the peripheral and central tissue, but a smooth gradation from the small peripheral to the large central cells (Fig. 8), while the cell contents are usually dense, brown, and granular. It is important that the section examined should be from a sufficiently mature portion of the plant, since just below the apices the tissue is not differentiated characteristically. Near the base of the plant secondary cortex is often particularly well developed, in f. *secundata* this tissue being at times as wide as the whole of the primary tissue. An attempt to distinguish the forms of this species by means of the degree of development of this secondary cortex was not successful, since its non-occurrence may be due merely to the immaturity of the

specimen examined. However, it is very frequently developed in f. *secundata,* less frequently in f. *flagellifera,* only rarely in f. *pseudoflagellifera,* and has not been observed in f. *compacta.*

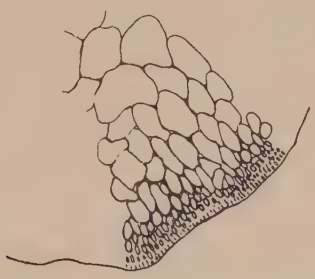

FIG. 8.—Portion of the transverse section of the thallus of *G. secundata* f. *secundata.* Gradation in size of cells is shown. Approx. × 40.

*G. furcellata* differs from *G. secundata* in its prevalently dichotomous branching, tufty habit, and in being obviously thickened toward the base.

*G. Harveyana* f. *Harveyana* may at times appear very similar to the coarse *G. secundata* f. *secundata. G. Harveyana* differs, however, in having its branches less close and hence less imbricate, and the base usually much coarser than the remainder of the plant.

*G. armata* (Ag.) J.Ag. from Italy (Herb. NSW) and the Adriatic (Herb. MEL) appears allied to *G. secundata,* from which it differs by being armate.

*G. secundata* f. *flagellifera* shows affinity with *G. tenax* J.Ag., formerly confused with *G. dura* (Ag.) J.Ag. The habit of the latter is, however, more tufty than is usual in *G. secundata* f. *flagellifera.* For this comparison a plant (from Herb. MEL) from Antigua, West Indies (coll. 1853) was examined.

Laing (1939) lists *G. dura* as possibly from New Zealand. This record seems very likely to refer to a form of *G. secundata,* which is prevalent in New Zealand waters.

*G. secundata* is widely distributed in Australian waters, but is particularly well developed in southern latitudes. It is recorded only from Australian and neighbouring waters (Western Australia to Chatham Island).

Variations in form in this species are apparently related to a certain extent to variations in habitat, the coarser plants being those on headlands exposed to surf action, and the finer plants extending into estuarine waters. Forma *compacta* (q.v.) may perhaps be limited to a particular substrate.

*G. secundata* grows throughout the year, being most abundant and bearing reproductive structures most frequently in the summer months, viz., December-January.

*Key to the Forms of* G. secundata

1. Branching mainly secund, distichous, or trichotomous. Habit half-tufty.
   2. Plant coarse (0·7–1·5 mm. in width), compressing little on drying .. .. f. *secundata* (page 48).
   2′. Plant finer (width up to 1·0 mm.), less cartilaginous, and compressing more on drying .. .. .. .. f. *flagellifera* (page 49).

1′. Branching from all sides of the plant, sometimes secund for a short distance.
   3. Plant up to 15 cm. long. Branches evenly distributed, i.e., not predominantly from near base. Habit tufty to half-tufty .. f. *pseudoflagellifera* (page 51).
   3′. Plant small (to 4 cm. long), much branched near the base. Habit tufty. Growing on shells .. .. .. .. f. *compacta* (page 53).

**G. secundata f. secundata (Harv. sensu orig.) stat. nov.**

*Gracilaria secundata* Harv. 1863, *Phyc. Aust.*, No. 432; J.Ag. 1876, *Epicr.*, 418; De Toni 1897, *Sylloge Algarum*, 440-1.

*Standard specimens examined.*—Harv. Alg. Aus. Exsicc., No. 325, New South Wales (Herbs. NSW, MEL) previously labelled *G. secundata.* The type material of the form is that of the species and has been discussed under that heading.

The coarsest examples of *G. secundata* are from ocean headlands exposed to rough surf action (as shown in Plate 11, Fig. 3). Harvey's material is less coarse than most of that to be found in exposed situations along the coast of New South Wales. His specimens are almost intermediate between the coarse, tough form included in f. *secundata,* and the finer, softer plants of f. *flagellifera* (q.v.).

Thallus very variable in length (Plate 11, Figs. 1, 2, and 3), but usually less than 40 cm., 0·7–1·5 mm. or more in width, with the axes usually terete, but the main axes sometimes ellipsoidal or flattened. Primary branches arising from a disc base, the secondary branching secund, sometimes distichous, with occasional dichotomy near the apices, sometimes forming a dense mass of branches towards the apex and occasionally the branching at the apices actually corymbose. Secondary branches with few, if any, subsidiary branches, usually narrowing at their insertion. Proliferations of numerous branch initials sometimes developed from the main axis. Cystocarps varying greatly in size even on a single branch, and occurring mainly in the upper half of the plant.

Laing (1939) doubts whether the specimens of *G. secundata* from New Zealand and Australia are identical; however, the present writer considers that *G. secundata* f. *secundata* definitely occurs in both countries. Comparable plants from both localities are illustrated in Plate 11, Figs. 2 and 3.

Specimens of this form are frequently found as drift on the shore, but occur on rocks or in pools far out on surf headlands, and may be collected by wading at very low tide.

*Localities*

*New South Wales.*—New South Wales, Collie 3 (MEL). Newcastle, Harvey 325 (NSW, MEL). Port Jackson, Stephan (NSW). Ocean shore, near Sydney: 2/1922 (AHSL); Bondi, Lucas, 12/1899 (NSW); Bondi, Lucas, 1/1911 (NSW, AHSL); Bondi, Evans, 3/1924 (SYD); Bondi, Lucas, 4/1926 (AHSL, SYD); Careel Head, Whale Beach, below L.T.L., 1/1946 (VM 1188); Collaroy, drift, 11/1944 (VM 439); Collaroy, drift, 12/1944 (VM 440); Long Bay, Lucas, 7/1902 (NSW); Malabar, on rock, always submerged, 7/1945 (VM 841); Manly, 1884 (UM); Maroubra Bay, Lucas, 7/1901 (NSW, AHSL); Maroubra Bay, Lucas, 10/1931 (AHSL, SYD); Newport, in deep rock pool, 10/1944 (VM 798); Newport to Bilgola Headland, in rock gutter, 11/1945 (VM 915). Botany Bay, trawled (VM 800). Port Hacking, 9/1944 (VM 107).

Additional localities, C.S.I.R.—Laurieton.

*Victoria.*—Victoria. Lucas, 1/1900 (NSW). Barwon Heads, Lucas, 1/1900 (NSW).

*Lord Howe Island.*—Lord Howe Island, Maiden, 3/1898 (NSW).

*New Zealand.*—Chatham Island, VWL 2138, 3/1941 (VM). Otago, Brighton, DSIR 39099 a & b, 4/1940 (VM). Stewart Island, VWL 3091, 2/1943 (VM). Timaru, Patiti Point, rocks, exposed at low tide, DSIR 44554, 2/1944 (VM).

**G. secundata f. flagellifera (J.Ag.) stat. nov.**

*Gracilaria flagellifera* J.Ag. 1876, *Epicr.*, 412; 1879, *K. Svenska Vet.-Akad. Handl.*, 15 (6), tab. 24, figs. 1-6; 1874, nomen nudum, *Trans. N.Z. Inst.* 6, 209; De Toni 1897, *Sylloge Algarum*, 430.

*Standard specimens examined.*—In Agardh (1879, tab. 24) is a clear illustration of *G. flagellifera*, from Chatham Island. This, together with collections (from Herbs. DSIR and VWL) of *Gracilaria* from the type locality of Chatham Islands (e.g. Herb. VWL, No. 2979), is the basis for my use of the name *flagellifera* here.

Branching predominantly secund (Plate 12, Figs. 1 and 2). Width of axes sometimes variable. Differing from f. *secundata* in being less cartilaginous and tough thus compressing more on drying, generally finer and smaller (width 0·4–1·0 mm., length up to 30 cm.), and in the constriction at the insertion of a branch often more marked.

A series of plants intermediate between this form and *G. secundata* f. *secundata* have been examined. For this reason *G. flagellifera* is reduced in status to that of a form. As stated under f. *secundata,* Harvey's specimen from Newcastle is less cartilaginous than is usual for that form and habitat, so that actually it approaches f. *flagellifera.*

In Australian specimens f. *flagellifera* usually occurs in habitats not subjected to such strong surf action as is endured by *G. secundata* f. *secundata.* In the New Zealand material, however, f. *flagellifera* (Herb. DSIR, No. 42128, Plate 12, Fig. 1) is recorded as " on rocks in sand on open coast."

The New Zealand material I have seen shows a particularly high proportion of trichotomous branching (Herb. VWL, Nos. 2979, 3837, 4428; Herb. DSIR, Nos. 46802, 46807*a*). In some cases at least (Herb. DSIR, No. 46807*a*) this appears to be the result of regeneration following injury. Further study of more numerous collections would be necessary before one could decide whether plants showing this trichotomous branching are sufficiently numerous to constitute a distinct form. However, both forms of branching can occur on the same specimen. This kind of variation is also represented in Australian material (Herb. AHSL, from Snug, Tas.); it was recorded also by De Toni (1897, p. 430).

Specimens collected by R. Gunn, from Tasmania (Herbs. NSW and MEL, Communicat ex Herb. J. G. Agardh), are here referred to *G. secundata* f. *flagellifera.* These specimens were quoted by J. Agardh (1876) as *G. spinescens,* but Lucas (1909) considered this identification " doubtful." These Tasmanian specimens display rather more dichotomy than is usual in *G. secundata,* and so suggest transition to *G. furcellata* f. *ramulosa* (q.v.).

The differentiation of *G. confervoides* f. *ecortica* and *G. secundata* f. *flagellifera* on external character may be very difficult when both plants are elongated and with lateral or secund branching. However, these forms differ in the structure of the thallus as shown in a transverse section of a mature plant (Diagram 2) and in the usually somewhat more limited habit of growth of *G. secundata.* It is likely that the record of *G. confervoides* from Tasmania, reported by Lucas in 1928 as " Derwent (Rodway, Lucas)," is based upon specimens cited in the present paper as *G. secundata* f. *flagellifera.*

*Localities*

*Victoria.*—Port Phillip: (MEL); Heads, Wilson, 1/1886 (MEL); Stn. 14, Wilson, 12/1887 (MEL); Symonds Channel, 7 f., Wilson, 1/1884 (MEL).

*Tasmania.*—Tasmania: (MEL); Gunn (NSW); Gunn, ex Herb. J. G. Agardh (MEL); Ad lit. orientale, Stuart (MEL). Derwent River: Rodway (AHSL); Rodway, R.H. 83 (HO); Rodway, 11/1909 (AHSL, SYD); Sandy Bay, Rodway, 1/1909 (AHSL); Sandy Bay, Rodway, R.H. 83, 4/1912 (HO); Sandy Bay, Hobart, Lucas, 9/1925 (AHSL 7 *et al.,* SYD).

Georgetown, Lucas, 1/1902 (AHSL). Orford: , (MEL); Meredith (NSW). Snug, Lucas, 11/1925 (AHSL). Tamar River, Lucas, 1/1928 (AHSL).

*New Zealand.*—Chatham Island: DSIR 46802, summer 1943 (VM); VWL 2979, 1/1943 (VM). Dunedin, Brighton Beach, VWL 4428, 7/1944 (VM). Otago: Brighton Beach, VWL 4701, 10/1944 (VM); Moeraki, DSIR 46230, 5/1944 (VM); Moeraki, DSIR 46807*a*, 11/1941 (VM). Stewart Island: VWL 3779, 6/1943 (VM); VWL 3837, 9/1943 (VM); VWL 4490, 7/1944 (VM); VWL 3781, 6/1943 (VM); Half Moon Bay, DSIR 24082, 1/1940 (VM). Wellington, Island Bay, rocks in sand on open coast, DSIR 42122, 42128, 12/1932 (VM).

**G. secundata f. pseudoflagellifera forma nov.**

Affinis f. *flagelliferae,* sed frondibus angustioribus brevioribus, minus cartilagineis, irregulariter quoquoversum exeuntibus, rarius secundis, differt.

Habit tufty to half-tufty; thallus up to 15 cm. in length, 0·2–0·7 mm. in width, but the width of the axis sometimes inconstant (Plate 13, Fig. 1). Branches characteristically tapering at their insertion, but not invariably. Cystocarps varying in shape, but usually beaked, the beaks being more prominent generally in the finer tuftier plants.

Differs from f. *flagellifera* in the irregular, less frequently secund branching arising from all sides of the main axis, and in being finer, shorter, and less cartilaginous.

To this form belongs Lindauer's Alg. N.Z. Exsicc., No. 141, Ninety Mile Beach (Herb. VM), previously labelled *G. Harveyana.* It is possible that other New Zealand material previously labelled *G. Harveyana* may also prove to be *G. secundata* f. *pseudoflagellifera.*

*G. Harveyana* and *G. secundata* are closely allied, and f. *pseudoflagellifera* might perhaps equally well be considered as a form of the one as of the other. However, f. *pseudoflagellifera* is preferably considered as a form of *G. secundata,* because in this species there exists a series from f. *compacta,* via f. *pseudoflagellifera,* and f. *flagellifera* to f. *secundata.* In all these forms the structure shown in the transverse section of the thallus, the insertion of the branches, and the fairly pointed apices are alike. In this series the coarseness and size of the plant generally increases, and the branching becomes less imbricate and more secund. In *G. Harveyana* on the other hand, branching is never imbricate, and the plant usually shows a decided increase in width near its base.

Coarser larger plants of f. *pseudoflagellifera* grade toward f. *flagellifera.* On the other hand, small plants with rather more branching near the base than is usual in the form grade toward f. *compacta.* One such specimen (Herb. VWL, No. 1272) grew attached to shellfish—which is the only substrate recorded for f. *compacta.*

Gradation in cell size, as shown in a transverse section of the thallus, is sometimes less marked in f. *pseudoflagellifera* than in other forms of G. *secundata,* and secondary cortex is generally lacking, so that this form shows a gradation towards the Macrocystideae. Many specimens are very fine in habit and so resemble *G. confervoides* f. *gracilis,* under which the similarity of the two is discussed.

Most specimens (and the type) of f. *pseudoflagellifera* come from New Zealand. To this form also belongs material from Leighton, Western Australia, and from Tasmania (Plate 13, Fig. 2). It is unusual to find the one form so widely distributed with so few collections representing it in the intervening waters. The type specimen of the form is from the herbarium of V. W. Lindauer, No. 2088, now in my own herbarium (Plate 13, Fig. 1).

It is possible that the record (Laing 1939) of *G. confervoides* occurring in New Zealand refers to the present form. The only material available to me labelled by R. M. Laing as *G. confervoides* (q.v.) has proved to be *G. secundata* f. *pseudoflagellifera.*

Forma *pseudoflagellifera* has been collected during most months of the year, and cystocarps have been found from December to May.

*Localities*

*Tasmania.*—Georgetown, Perrin & Lucas, 1/1930 (AHSL). Low Head, Lucas, 1/1927 (AHSL 5 *et al.,* SYD).

*Western Australia.*—Leighton: 4/1941 (UWA); drift, 4/1941 (VM 902); 4/1943 (UWA).

*New Zealand.*—Akaroa foreshore, Laing 237, 2/1935 (VM). Auckland, Onehunga, on broad sandy tidal flat, DSIR 40126, 10/1943 (VM). Auckland North, Leigh, high-level tidal pool, DSIR 28431, 10/1940 (VM). Argyle Beach, The Bluff, VWL 4167, 2/1944 (VM). Bluff Harbour, DSIR 34015, 34016, 1/1941 (VM). Chatham Island, DSIR 46800, summer 1943 (VM). Doubtful Sound, Deep Cove, DSIR 24100, 12/1939 (VM). Dunedin, St. Clair, open coast, DSIR 46806*a*, 3/1916 (VM). Indigo's Bay, Urupukapuka, on gasteropod spires, below L.W.M. on shallow beach, VWL 1272, 2/1939 (VM). Nelson, VWL 1733, 2/1940 (VM). Ninety Mile Beach: The Bluff, in pool at H.W.M., VWL 2088, 1/1941 (VM); Lindauer, 141, 1/1941 (VM). Otago, Brighton, DSIR 46805*b*, 12/1937 (VM). Otago Harbour, Portobello, DSIR 46801*b*, 4/1938 (VM). Stewart Island: VWL 3840, 9/1943 (VM); VWL 3906, 11/1943 (VM); VWL 5975, 4/1945 (VM); VWL 6008, 4/1945 (VM). Tauranga Harbour, on cockle shells, DSIR 34093, 2/1941 (VM). Waitara, Taranaki, VWL 4556, 8/1944 (VM). Wellington Harbour: Karaka Bay, rocks in sand, DSIR 28606, 11/1940 (VM); Lowry Bay,

drift, DSIR 40078, 9/1943 (VM); Muritai, drift, DSIR 40209, 10/1943 (VM); Oriental Bay, DSIR 46803*a*, 46804, 1/1940 (VM); Titahi Bay, brackish pool, DSIR 34285, 5/1941 (VM); Worsor Bay, on rocks in sand, DSIR 42051, 11/1943 (VM).

**G. secundata f. compacta forma nov.**

Affinis f. *pseudoflagelliferae*, sed frondibus minoribus, ramulis densioribus, saepe radice exeuntibus, minus frequenter tenuibus ad junctiones, et abruptiore contractis ad apices, differt. Hab. conchis.

Thallus up to 4 cm. in length, and up to 0·6 mm. in width. Erect axes in parts bearing secund branches, but near the base the branches much more frequent and irregularly arranged. Cystocarps in clusters and generally beaked.

Differs from other forms of *G. secundata* in being smaller, much more compact in its branching and therefore tufty in habit, and the branches more frequent near the base of the plant, often less constricted at their insertion, and thinning more abruptly toward their apices.

In the material I have examined, no secondary cortex has been developed, though, as remarked elsewhere, the occurrence of this tissue may depend on the maturity of the specimen.

This small form is not merely a juvenile stage of *G. secundata,* since both cystocarps and tetraspores are known (Herb. VWL, No. 1998, which includes the type specimen). So far I have seen this form only from two localities and both specimens were found on dead bivalves (Plate 14, Fig. 1). No. 1998 is recorded as "on dead bivalves . . . . on bottom of loose sand in estuary of river."

Since the branching is not regularly secund, and since this is a shorter, softer plant than f. *secundata* or f. *flagellifera,* this form shows closest affinity to f. *pseudoflagellifera* (Diagram 2). A transitional specimen between these two forms is discussed under f. *pseudoflagellifera.*

I understand that this form has been distributed in Lindauer's Alg. N.Z. Exsicc. No. 167, Fasc. 7, February 1946.

*Localities*

*New Zealand.*—Scudder's Beach, on dead bivalves, VWL 1757, 2/1940 (VM). Taharonui River Mouth, on dead bivalves on bottom of loose sand in estuary of river, VWL 1998, 12/1940 (VM).

### 8. Gracilaria furcellata Harv.

*Gracilaria furcellata* Harv. 1863, *Phyc. Aust.,* Pl. 286 (excl. synon.).

Habit tufty, up to 30 cm. long (usually 10–20 cm.), the branching close and imbricate, prevalently dichotomous, sometimes with additional lateral branches, which may taper at the insertions. Thallus usually tough and cartilaginous, adhering poorly to paper on drying, terete, and in transverse section (Fig. 9) showing serial gradations in cell size from the peripheral to the central cells (Microcystideae); cell contents usually dark and granular; secondary cortex usually well developed (but absent in f. *ramulosa*).

In *G. lichenoides,* another tufted species which may develop dichotomous branching, the transverse section of the thallus may occasionally display a certain degree of gradation in cell size among the central cells; in this way this species approaches *G. furcellata.* Generally, however, the structure of the transverse section of the thallus will separate these species very clearly.

FIG. 9.—Portion of the transverse section of the thallus of *G. furcellata* f. *furcellata.* Secondary cortex and gradation in cell size are shown. Approx. × 40.

*G. furcellata* is known only from Australia (De Toni 1924).

*Key to the Forms of* G. furcellata

1. Plant thickening markedly toward the base .. .. f. *furcellata* (page 54).

1′. Plant not thickening markedly toward the base; apices less acute .. .. .. .. .. f. *ramulosa* (page 56).

**G. furcellata f. furcellata (Harv. sensu orig.) stat. nov.**

*Gracilaria furcellata* Harv. 1863, *Phyc. Aust.,* Pl. 286 (excl. synon.); J.Ag. 1876, *Epicr.,* 419; De Toni 1897, *Sylloge Algarum,* 441-2.

*Standard specimens examined.*—Harv. Alg. Aus. Exsicc. No. 323, Western Australia (Herbs. NSW, MEL), previously labelled *G. confervoides.*

Thallus tufty, up to 30 cm. in length. Branching dichotomous-fastigiate. Structure of thallus in transverse section as in the Microcystideae. Branch width 0·4–1·4 mm. near the base of the plant, generally decreasing markedly toward the apices, but juvenile material sometimes showing less of the characteristic thickening near the base. Cystocarps varying in external shape, even in a single plant.

Sometimes, as in specimens collected at Esperance, W.A. (Herb. AHSL), the basal axis is particularly coarse in comparison with the whole plant, but even in a single collection (Herb. VM 688, Slopen Island, Tas.) variations in this proportion occur, so that this difference is merely an individual variation.

It seems probable that *G. furcellata* f. *furcellata* was the species and form referred to as " perhaps . . . . a variety of *G. confervoides* Grev." (Anon. 1866-7) and recorded as used in Tasmania for making jelly; it was stated to

be "abounding on the shores of Sloping (or Slopen) Island, in Frederick Hendrick Bay, Tasmania." Material from this locality collected by M. Blackburn, 3/1945 (Herb. VM 688) is *G. furcellata* f. *furcellata.*

*G. fruticosa* Harv. (q.v.) and *G. furcellata* Harv. are both recorded from Victoria by Wilson (1892, p. 176) and Tisdall (1898). These two specific names are attached respectively to two of Wilson's specimens (Herb. MEL) which match each other particularly well and which are both *G. furcellata* f. *furcellata.*

*G. furcellata* is compared with *G. secundata* under the latter heading. *G. furcellata* is closely related to *G. Harveyana,* but differs from it in that its branching is much more prevalently dichotomous, dense and imbricate, the plant being more tufted. These two species approach each other through *G. Harveyana* f. *nana* and *G. furcellata* f. *furcellata,* and the collection quoted above (Herb. VM 688) shows certain plants which grade toward f. *nana.*

*G. furcellata* f. *furcellata* has been collected during most months of the year, and cystocarps have been found in summer, autumn, and winter.

*Localities*

*Victoria.*—Victoria, Lucas, 1/1900 (AHSL 9 *et al.,* SYD). Western Port: Wilson, 4/1890 (MEL); Flinders, Lucas, 2/1932 (AHSL, SYD); Phillip Island, Mueller, 2/1863 (MEL). Port Phillip: (NSW, MEL); 166 (MEL); Mueller, 8/1854 (MEL); Lucas, 1/1900 (AHSL); Heads, Stn. 1, Wilson, 12/1891 (MEL); Heads, Stn. 3, Wilson, 1/1895 (NSW); Heads, Stn. 8, Wilson, 4/1888 (MEL); Point Lonsdale, Lucas, 1/1932 (AHSL); Point Lonsdale, Brookes, 2/1932 (AHSL); Portsea, Lucas, 1/1919 (AHSL); St. Leonards, Lucas, 1/1933 (NSW, AHSL, SYD); Sorrento, Lucas, 6/1926 (AHSL); W. Channel, Wilson, 4/1887 (NSW); Williamstown, Lucas, 1/1900 (AHSL, SYD); Williamstown, Lucas, 2/1900 (AHSL).

*Tasmania.*—Tasmania: Quayfe (AHSL); Archer (NSW, AHSL). Tasmania orientalis (MEL). Georgetown, Perrin & Lucas, 3/1934 (AHSL). Low Head, River Tamar: Perrin & Lucas, 1/1931 (NSW, AHSL); on muddy rocks near L.T.I., Gordon, 2/1942 (TAS). Slopen Island, Frederick Henry Bay, 3/1945 (VM 688).

*South Australia.*—Lacepede Bay, Engelhardt, 1895 (MEL). Encounter Bay, Cleland (AHSL). Kangaroo Island, Pennington Bay, drift, 5/1945 (VM 878).

*Western Australia.*—Geraldton, Lucas, 7/1928 (AHSL). Dongarra, Back Beach, on reef side, 2/1944 (UWA). Denisson Reef, South End, drift, 2/1944 (UWA). Fremantle: (MEL); Harvey 323 (MEL, NSW). Swanbourne: attached to rocks in tidal zone, Banks, R85, 2/1927 (AHSL, SYD); Banks, R86, 2/1927 (AHSL). Cottesloe: on reef, 11/1930 (UWA); Burbidge, 6/1934 (UWA). Albany, High School (AHSL). Esperance, Picnic Cove: Burbidge 33, 1/1935 (UWA); Burbidge 34, 1/1935 (AHSL).

**G. furcellata f. ramulosa (J.Ag.) stat. nov.**

*Gracilaria ramulosa* J.Ag. 1876, *Epicr.*, 417; De Toni 1897, *Sylloge Algarum*, 439; *Gracilaria* sp. Harv. 1863, *Phyc. Aust.*, No. 426.

*Standard specimens examined.*—Harv. Alg. Aus. Exsicc. No. 324, Western Australia (Herbs. NSW, MEL), previously labelled *Gracilaria* species.

Habit tufty. Branching dichotomous to corymbose, often with a strong development of lateral branches, the latter usually short, and sometimes secund in parts (Plate 14, Fig. 2). Structure of thallus as shown in transverse section as in the Microcystideae group of species, secondary cortex, however, not being developed.

Differs from f. *furcellata* in being of relatively uniform width throughout the plant, not thickening toward the base, and in having apices more rounded (less acute). The lack of secondary cortex and the relative uniformity of width throughout the plant suggest that this is merely an undeveloped or young form of *G. furcellata,* perhaps one from a distinctive habitat. The greater development of lateral branches represents, it seems, merely individual variation, as this differs from branch to branch. The acuteness of the apices varies, too, within a single plant, and does not provide a valid character for specific difference.

*G. furcellata* f. *ramulosa* approaches *G. lichenoides* f. *taenioides,* from which it differs mainly in the structure shown in the transverse section of the thallus. These forms are shown linked in Diagram 2.

Laing (1939) records this form (as *G. ramulosa* J.Ag.) as perhaps occurring in New Zealand.

There is a specimen of this form (Herb. MEL) labelled (probably by Sonder) *Gracilaria* sp. from "Richmond River, Miss Hodgkinson". I know of no Richmond River near the other locations known for this form, and as the label is merely a loose slip of paper inserted in the folder, it seems more likely that the label has been inadvertently changed, rather than that a Western Australian form should be collected once on the east coast of Australia, a relatively more explored district.

*Localities*

*Western Australia.*—Geraldton Beach, 11/1943 (VM 810). King George's Sound, Harvey 324 (MEL, NSW).

### 9. Gracilaria Harveyana J.Ag.

*Gracilaria Harveyana* J.Ag. 1884, *Lund. Univ. Arssk.* 21, 59; De Toni 1897, *Sylloge Algarum*, 441 (excl. synon.); 1924, *Sylloge Algarum*, 257.

Habit half-tufty, thallus terete, up to 30 cm. long, when dry, dark-red and tough cartilaginous, not adhering to paper on drying. Branching generally widely spaced and irregular, sometimes in part secund, the branches showing a rather characteristic tapering at their insertions (Plate 15, Fig. 1). Thallus

in transverse section showing gradation in cell size, there being no sudden junction of small peripheral with the large central cells (Microcystideae); cell contents often densely granular, and secondary cortex often well developed. Cystocarps generally only on apical portions of plant.

There is a range in size in this species, the smaller, finer, more tufted form found in Tasmania grading toward *G. furcellata* f. *furcellata,* and the larger, coarser, and less tufted form from Western Australia more closely resembling *G. secundata* f. *secundata.* Some of the material (Herb. MEL) from Geographe Bay, W.A., grades toward *G. secundata.* Reinbold (1898, 1899) listed *G. Harveyana* among the algae from South Australia and emphasized its likeness to *G. secundata* and *G. flagellifera* (the latter is regarded in this paper as merely a form of *G. secundata*).

As just stated, *G. Harveyana* is allied to both *G. secundata* and *G. furcellata;* their resemblances are discussed under these species respectively. These three species form a natural group and are alike in the structure of the transverse sections of their thalli. They differ in that *G. furcellata* is tufty, the branching predominantly dichotomous and imbricate, the branches usually variable in width; *G. secundata* is tufty to half-tufty, the branching predominantly secund to trichotomous (though some forms are irregularly branched), the branches imbricate and uniform in width; *G. Harveyana* is half-tufty, irregularly, branched, the branches not imbricate, but variable in width. Of this series *G. Harveyana* is the most cartilaginous.

*G. armata* Grev., from the Adriatic, also seems to be allied to these three species, but differs in being armate.

*G. Harveyana* is known only from Australia (De Toni 1924, p. 257). Laing (1939) recorded it as possibly occurring in New Zealand, but this record probably refers to *G. secundata* f. *pseudoflagellifera* (q.v.).

*G. Harveyana* has been collected in various seasons, and cystocarps have been found in both summer and winter.

*Key to the Forms of* G. Harveyana

1. Plant large, coarse, up to 2 mm. in width at the base f. *Harveyana* (page 57).

1′. Plant smaller, less coarse, less than 1·5 mm. in width at the base .. .. .. .. .. f. *nana* (page 58).

**G. Harveyana f. Harveyana (J.Ag. sensu orig.) stat. nov.**

*G. Harveyana* J.Ag. 1884, *Lund. Univ. Arssk.* 21, 59; De Toni 1897, *Sylloge Algarum,* 441 (excl. synon.); 1924, *Sylloge Algarum,* 257.

*Standard specimens examined.*—I have examined specimens labelled Algae Muellerianae, Curante J. G. Agardh distributae, *Gracilaria Harveyana* J.Ag., from Geographe Bay, Champion Bay, and Swan River, W.A. (Herb. MEL).

The first-mentioned of these is likely to be from the collection to which J. Agardh made reference in his original description of the species (1884).

Thallus half-tufty in habit (illustrated in Plate 15, Fig. 1), coarse, up to 2 mm. wide at the base, rarely more.

*G. Harveyana* f. *Harveyana* is closely allied to *G. secundata,* from which it differs in being coarser and generally less imbricate in its branching and in the axis decreasing in width from the base to the apex of the plant. The largest, coarsest, and least imbricate form of *G. secundata* is f. *secundata,* specimens of which may appear very similar to *G. Harveyana* f. *Harveyana.* One atypical specimen of *G. Harveyana* f. *Harveyana* from Bunbury (Herb. UWA) bears from its secondary branches rather numerous, short, lateral branches, irregularly arranged and superimposed on the normal habit of branching; the upper part of this specimen thus appears like a coarse specimen of *G. secundata* f. *pseudoflagellifera.* In Diagram 2, both these forms of *G. secundata* are shown linked to *G. Harveyana* f. *Harveyana.*

*Localities*

*South Australia.*—Fowler's Bay, Richards (MEL).

*Western Australia.*—Geraldton: Lucas, 7/1928 (SYD); 11/1942 (VM 809). Dongarra, drift, 2/1944 (UWA). Champion Bay (Alg. Muell.) (MEL). Waterman's Bay, Williams, 5/1929 (UWA). Swan River, Jones (Alg. Muell.) (MEL). Cottesloe: (UWA); Lucas, 8/1928 (AHSL); Burbidge, 6/1934 (AHSL). Bunbury: Burbidge 18, 5/1934 (UWA); Lucas, 8/1928 (SYD). Geographe Bay: Bunbury (MEL); (Alg. Muell.) (MEL).

**G. Harveyana f. nana forma nov.**

Affinis f. *Harveyanae,* sed frondibus angustioribus (ad 1·0 mm.), minus cartilagineis, differt.

With the characters of the species but smaller, softer, and finer. Plant width mostly less than 1·0 mm.

The type of this form (Herb. AHSL) is shown in Plate 15, Fig. 2; it is from Ralph's Bay, Tasmania, collected by L. Rodway in July 1910. It was regarded by A. H. S. Lucas as *G. confervoides.*

This may be a geographic form of the species, but as yet we have insufficient collections to be sure. Forma *nana* approaches *G. furcellata* f. *furcellata,* from which it differs in being less imbricate and dichotomous.

*Localities*

*Tasmania.*—Ralph's Bay: Rodway, 7/1910 (AHSL); Rodway, RH 83, 7/1910 (HO).

Additional localities, C.S.I.R.—D'Entrecasteaux Channel.

## 10. Species Incertae Sedis

These species have been described or recorded from Australia. There are no specimens of them available to the writer in Australia, nor are there any illustrations of them. In the absence of more information, these species are grouped as "species incertae sedis", and in the opinion of the writer must be disregarded pending the acquisition of more data about them.

### Gracilaria aculeolata Areschoug

*Gracilaria aculeolata* Areschoug 1855, *Act. Reg. Soc. Scient.* ser. 3, 1, 352; De Toni 1897, *Sylloge Algarum*, 435.

In the original description Areschoug was doubtful of the genus. No material is available to me for further study.

*Localities Recorded*

*South Australia.*—Aresch. (1855) Port Adelaide.

### Gracilaria bifaria J.Ag.

*Gracilaria bifaria* J.Ag. 1901, *Sp.* 3 (4) 55; De Toni 1924, *Sylloge Algarum*, 254.

No specimens of this species are available to me for study. According to J. Agardh (loc. cit.) this species belongs to the Macrocystideae, and it seems likely that it is merely a form of polytypic *G. lichenoides*.

*Localities Recorded*

*New South Wales.*—J.Ag. (1901) Port Stephens.

### Gracilaria paradoxa (Harv. ex J.Ag.) J.Ag.

*Gracilaria paradoxa* (Harv. ex J.Ag.) J.Ag. 1901, *Sp.* 3 (4), 67; De Toni 1924, *Sylloge Algarum*, 257.

J. Agardh (loc. cit.) considered this species to be a member of the Microcystideae, similar to *G. Harveyana*. It is recorded by Laing (1939) as perhaps occuring in New Zealand, but see page 16.

*Localities Recorded*

*Australia.*—J.Ag. (1901) W. and S. Australia.

### Gracilaria corniculata (R.Br. ex Turn.) J.Ag.

*Gracilaria corniculata* (R.Br. ex Turn.) J.Ag. 1852, *Sp.* 2, 595; J.Ag. 1876, *Epicr.*, 424; De Toni 1897, *Sylloge Algarum*, 451-2; *Fucus corniculatus* R.Br. ex Turn. 1810, *Fuci* 3, tab. 182.

The only specimens examined by me and suspected of being this species were two plants from the National Herbarium, Melbourne; these specimens match one another well and were filed in the same folder. One specimen was labelled *Chondroclonium corniculatum* Kg., which is a synonym *of G. corniculata,* according to De Toni (1897, p. 451). This specimen was determined by Kuetzing and came from Sullivan's Cove, Port Phillip, Victoria, Oct. 1840. The other specimen may well be from the same plant. It also is labelled

*Chondroclonium corniculatum* and from Port Phillip. In addition the words *Gracilaria corniculata* and the name Dr. F. v. Muller occur on the mounting paper. This material is thus likely to have been the basis for Harvey's record in 1863 of *G. corniculata* from Port Phillip. This record is the only reference to this species from the mainland of Australia.*

The structure of these specimens as shown in a transverse section of the thallus resembles that of a species of *Gigartina,* and so they cannot be considered as belonging to the genus *Gracilaria.* A portion of one of these plants has been sent to the British Museum for comparison with the type specimen of *Fucus corniculatus* R.Br. ex Turn., from Kent Island, off Australia. Unfortunately, war damage has so far prevented this comparison being made.

Weber van Bosse (1928) records *G. corniculata* from the Aru Islands.

*Localities Recorded*

*Bass Strait.*—R.Br. ex Turn. (1810) Kent Island.

**Gracilaria fruticosa Harv.**

*Gracilaria fruticosa* Harv. 1855, *Trans. Roy. Irish Acad.* 22, 551; 1855, Alg. Aust. Exsicc. No. 322; 1863, *Phyc. Aust.,* No. 427; J.Ag. 1876, *Epicr.,* 416; De Toni 1897, *Sylloge Algarum,* 437.

It is possible that *G. fruticosa* is a synonym of *G. furcellata.* In the National Herbarium of New South Wales there is a double series of most of Harvey's Alg. Aus. Exsicc., but No. 322 (*G. fruticosa*) is missing, although there are four specimens of the one species labelled No. 323, i.e., *G. furcellata.* If, as seems possible, there was an early confusion in the label numbers, then *G. furcellata* could well be a synonym of *G. fruticosa.* Further, the plants on which the record for *G. fruticosa* from Victoria were based (Wilson 1892) are preserved at the National Herbarium, Melbourne, and are in fact identical with *G. furcellata* (q.v.). Opposed to this suggested synonmy of *G. fruticosa* and *G. furcellata* is the inclusion, by J. Agardh (1901), of *G. fruticosa* in the series Macrocystideae, a series which does not include *G. furcellata.*

The name *G. furcellata* has been retained in this paper until the question of its synonymy with *G. fruticosa* can be settled.

*Localities Recorded*

*Western Australia.*—Harv. (1855) Fremantle.

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* In 1946 Tore Levring (A list of marine algae from Australia and Tasmania. *Medd. Göteborgs Bot. Trädg.* 16: 215-27) recorded *G. corniculata* from Queensland. In private correspondence Dr. Levring informs me that he has compared his specimen with authentic material of Agardh in the Lünd herbarium and that it is "no doubt identical with this species". Dr. Levring has kindly sent me a small portion of his Queensland specimen. This portion appears to accord extremely well with *G. lichenoides* f. *Lucasii.* The portion is, I think, too small for safe use as the basis of synonymy, but this evidence suggests the strong probability that *G. lichenoides* f. *Lucasii* and *G. corniculata* are in fact the same.

## IX. ACKNOWLEDGMENTS

I am most grateful to the officers in charge of the various herbaria listed in this paper for the loan of specimens and for facilities for working.

My thanks are due to Mr. George Shipp, of the University of Sydney, who has assisted me greatly by translating portions of J. Agardh's work of 1901, and also to Mr. Andrew Proctor, of the Council for Scientific and Industrial Research, Cronulla, who is responsible for the photographic plates in this paper.

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PLATE 1

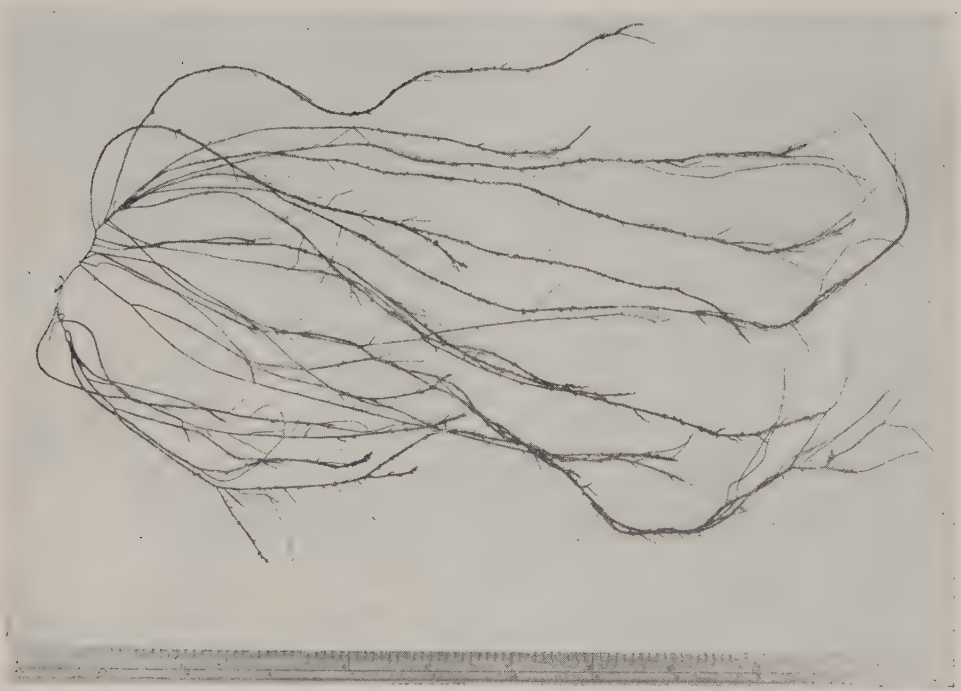

FIG. 1.—*Gracilaria confervoides* f. *confervoides*, from Doll's Point, Botany Bay, N.S.W., 9/1944 (VM 632).

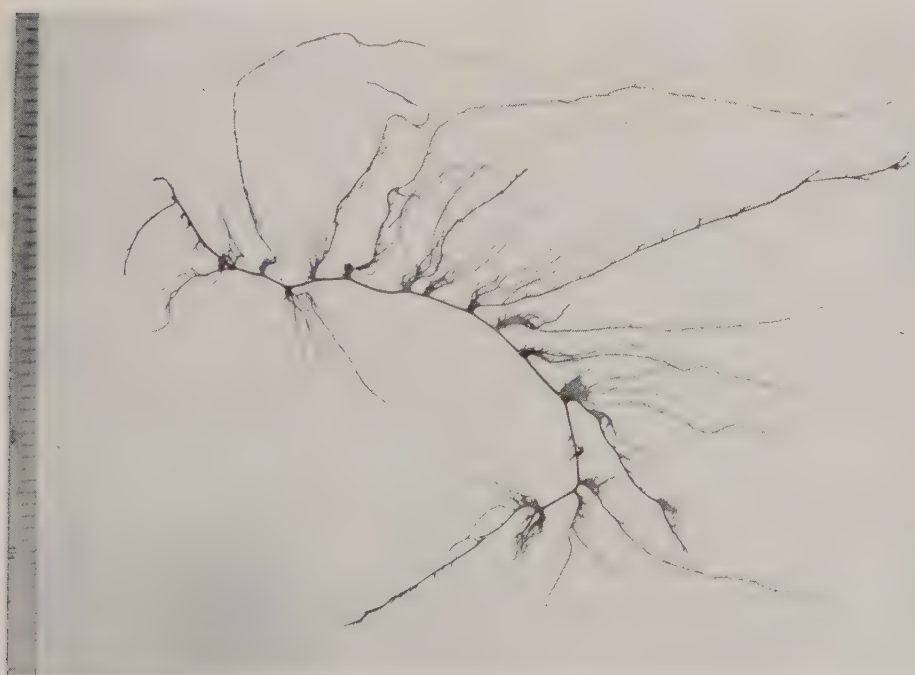

FIG. 2.—*Gracilaria confervoides* f. *ecortica*, showing fasciation in branching, from Farm Cove, Port Jackson, N.S.W., 1/1914 (SYD).

11427/47.—5

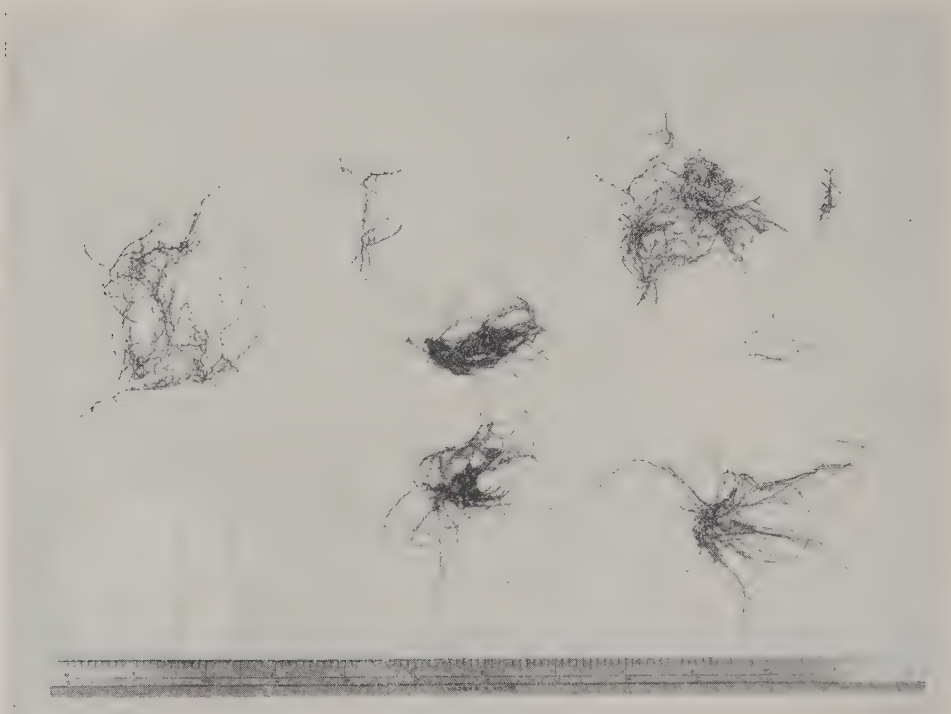

FIG. 1.—*Gracilaria confervoides* f. *gracilis*. from Kanahooka Point, Lake Illawarra, N.S.W., 3/1945 (VM 637).

FIG. 2.—*Gracilaria lichenoides* f. *lichenoides*, from Port Denison, Qld. (MEL).

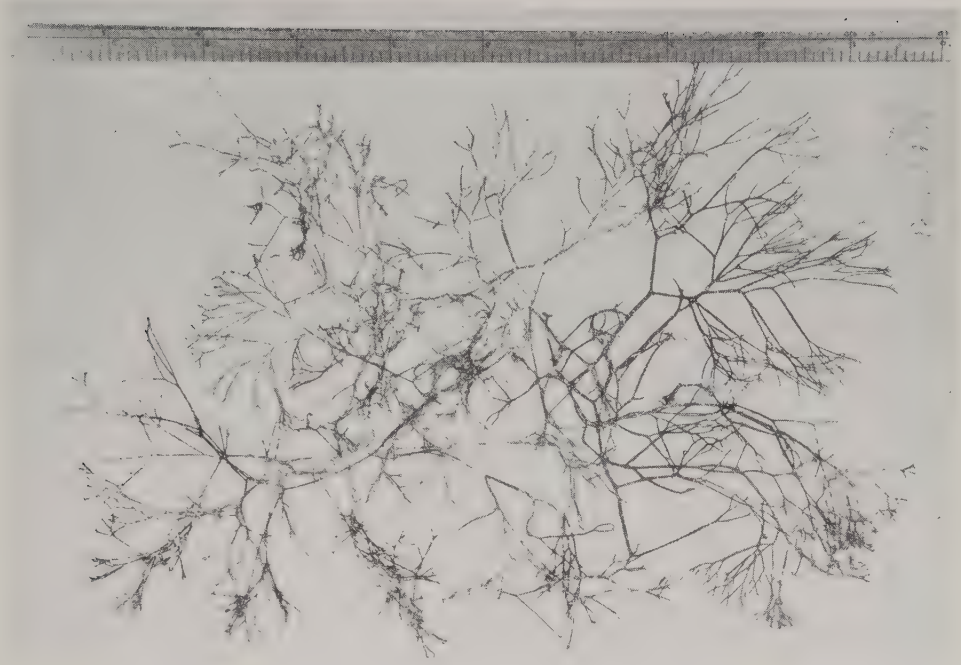

FIG. 1.—*Gracilaria lichenoides* f. *taenioides*, from Low Island, Qld., 5/1931 (AHSL 2).

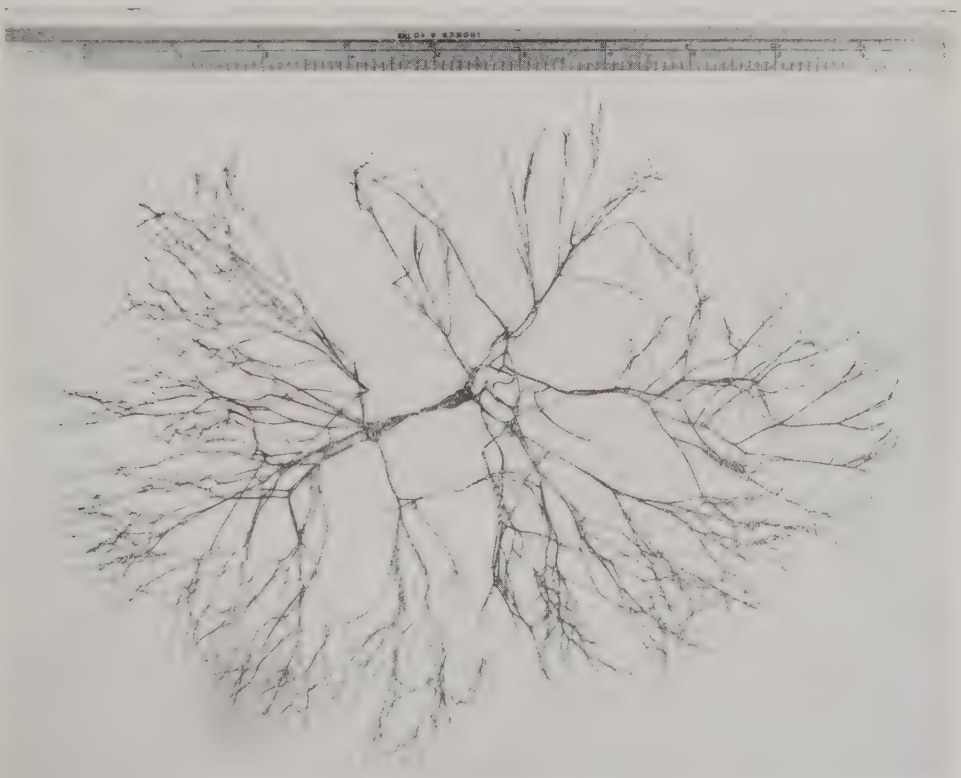

FIG. 2.—*Gracilaria lichenoides* f. *Lemania*, from Botany Bay, N.S.W., 4/1906 (AHSL 4).

FIG. 1.—*Gracilaria lichenoides* f. *Lemania*, from South Head of George's River Bridge, Botany Bay, N.S.W., 3/1945 (VM 542). (This specimen shows transition to f. *Lucasii*.)

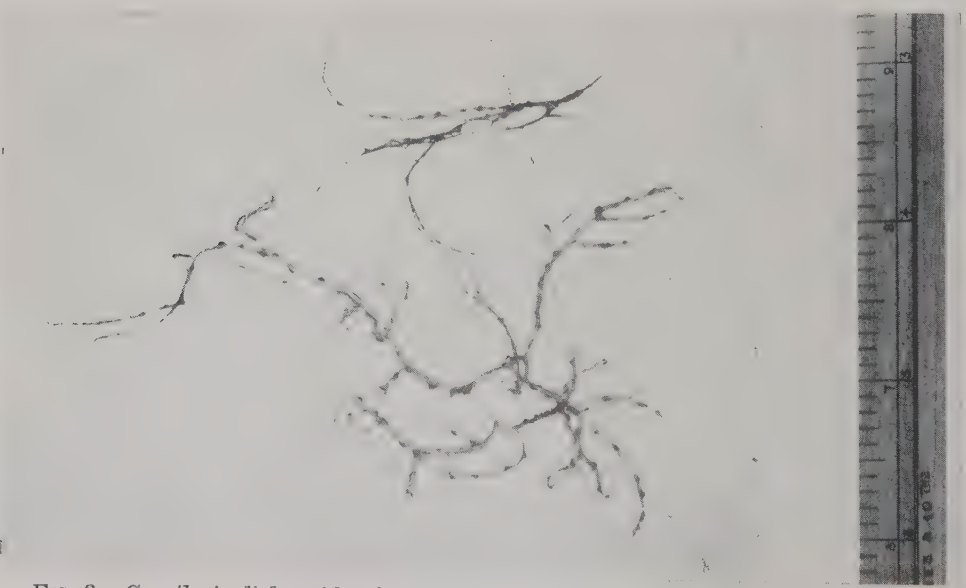

FIG. 2.—*Gracilaria lichenoides* f. *Lemania*, from Cape York, Qld. (MEL). (This specimen is Sonder's specimen of *G. Lemania*.)

PLATE 5

FIG. 1.—*Gracilaria lichenoides* f. *Lucasii,* from Farm Cove, Port Jackson, N.S.W., 1/1914 (AHSL).

FIG. 2.—*Gracilaria lichenoides* f. *polyclada,* from Port Denison, Qld., 1868 (MEL). (This specimen is Sonder's type of *G. polyclada.*)

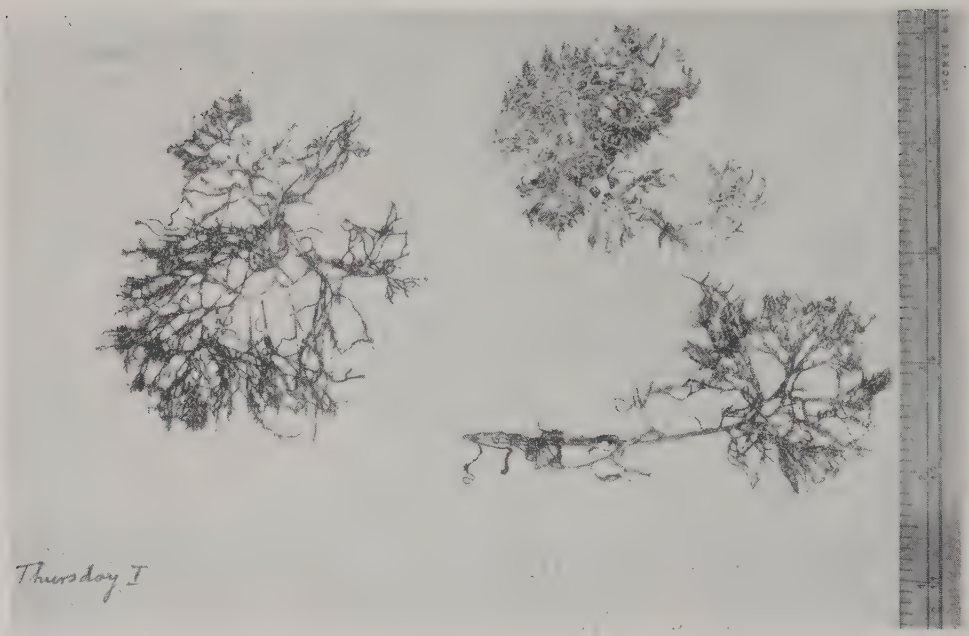


FIG. 1 (left).—*Gracilaria lichenoides* f. *coronopifolia*, from Thursday Island, off Qld. 10/1927 (AHSL).

FIG. 2 (right).—*Gracilaria lichenoides* f. *coronopifolia*, from Woahoo Island, Sandwich Group (MEL). (This specimen appears to be part of the type material of *G. coronopifolia*.)

FIG. 3.—*Gracilaria lichenoides* f. *coronopifolia*, from Port Denison, Qld. (MEL). (This specimen is Sonder's type of *G. lichenoides* var. *corniculata*.)

PLATE 7

FIG. 1.—*Gracilaria lichenoides* f. *complanata*, from Point Archer, near Cooktown, Qld., summer 1934-5 (AHSL). (Including the type of the form.)

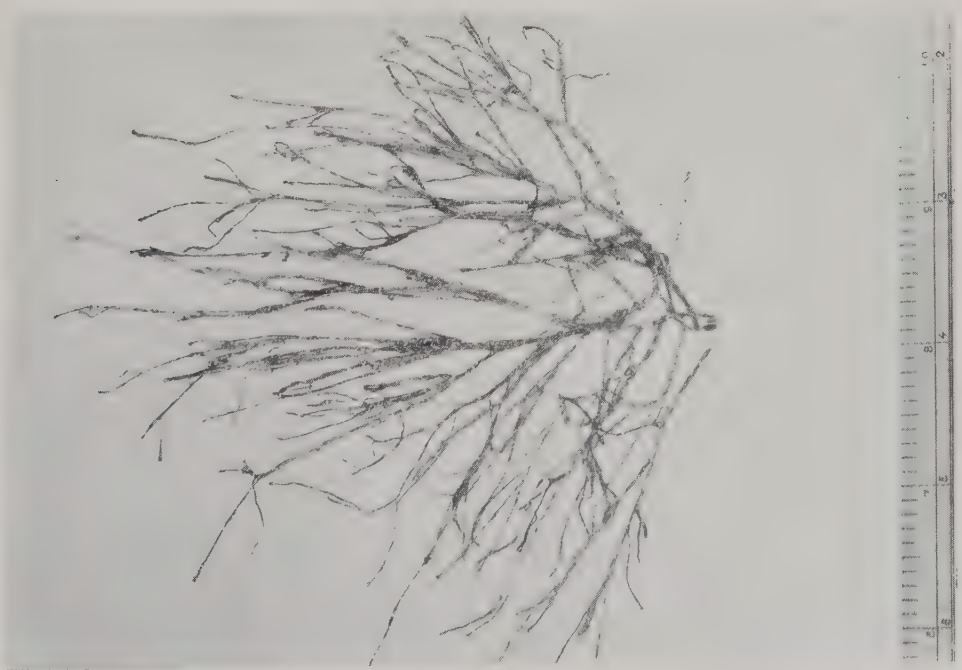

FIG. 2.—*Gracilaria lichenoides* var. *constricta*, from Dunk Island, Qld. (AHSL). (Apices frequently damaged.)

PLATE 8

FIG. 1.—*Gracilaria Howensis*, from Lord Howe Island, 3/1898 (NSW). (Type specimen.)

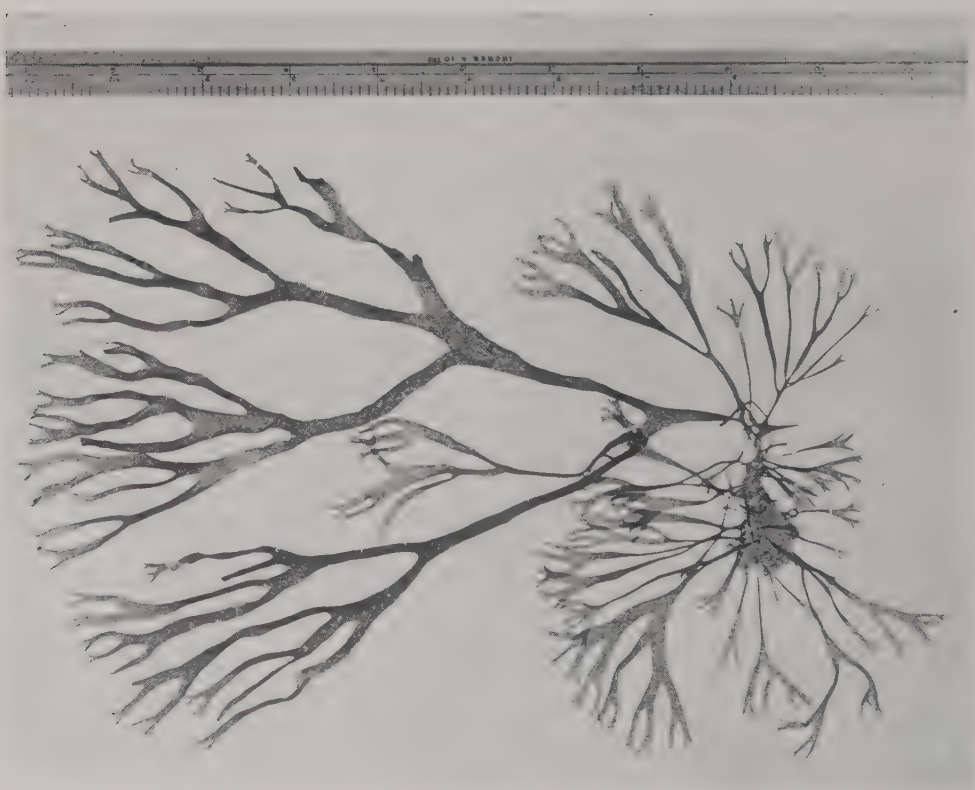

FIG. 2.—*Gracilaria Textorii* f. *Textorii*, from Botany Bay, N.S.W., 1/1905 (AHSL). (This specimen shows both dichotomous and proliferous modes of branching.)

PLATE 9

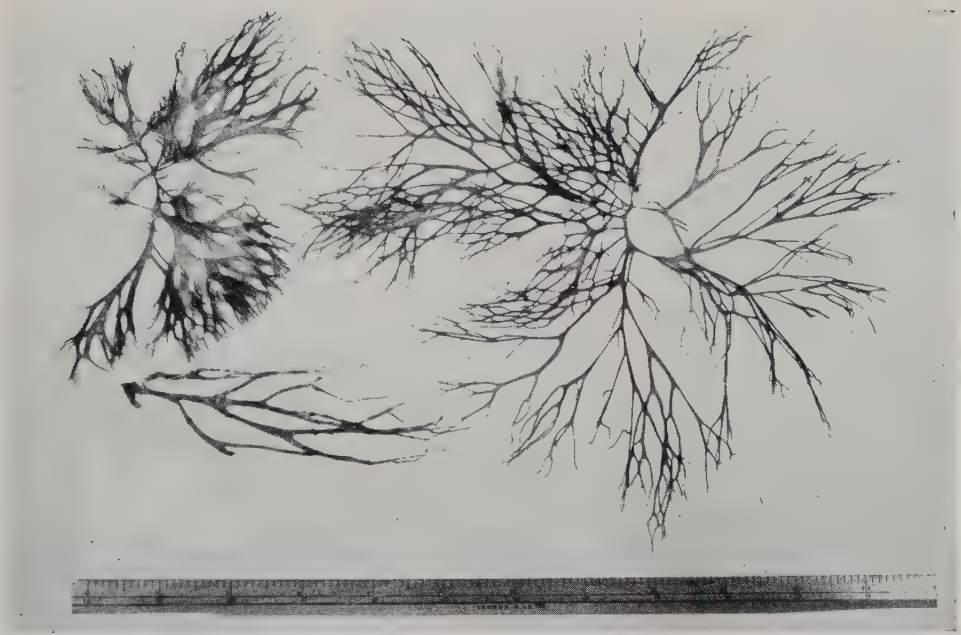

FIG. 1.—*Gracilaria Textorii* f. *Textorii* (showing variations in habit), from Fisherman's Island, Moreton Bay, Qld., 12/1943 (VM 795).

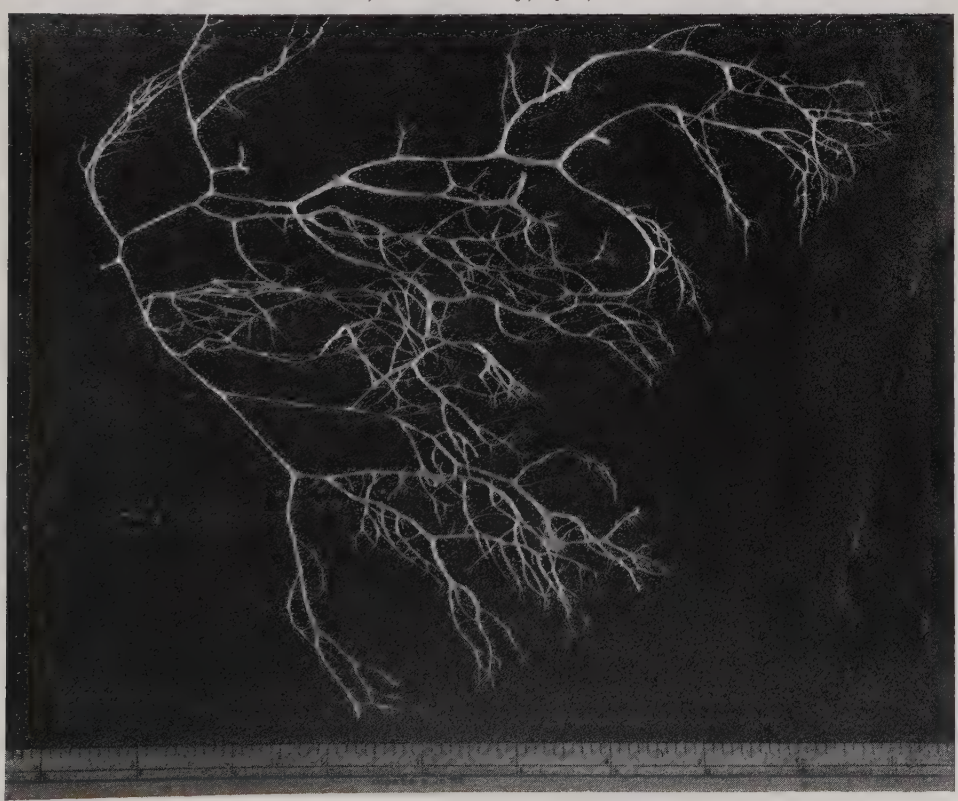

FIG. 2.—*Gracilaria Textorii* f. *tenius*, from Lamb Island, Moreton Bay, Qld., 5/1943 (VM 796). (This is the type of the form.)

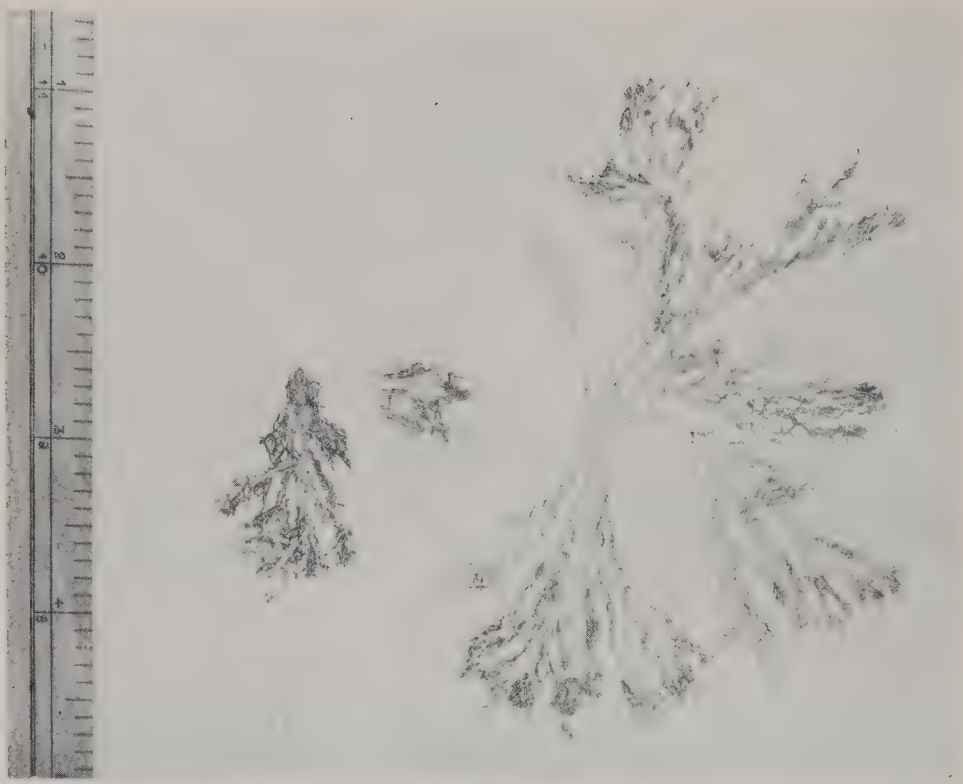

FIG. 1.—*Gracilaria pannosa*, from Champion Bay, W.A. (MEL). (This specimen is one of Algae Muellerianae J. G. Agardh distributae.)

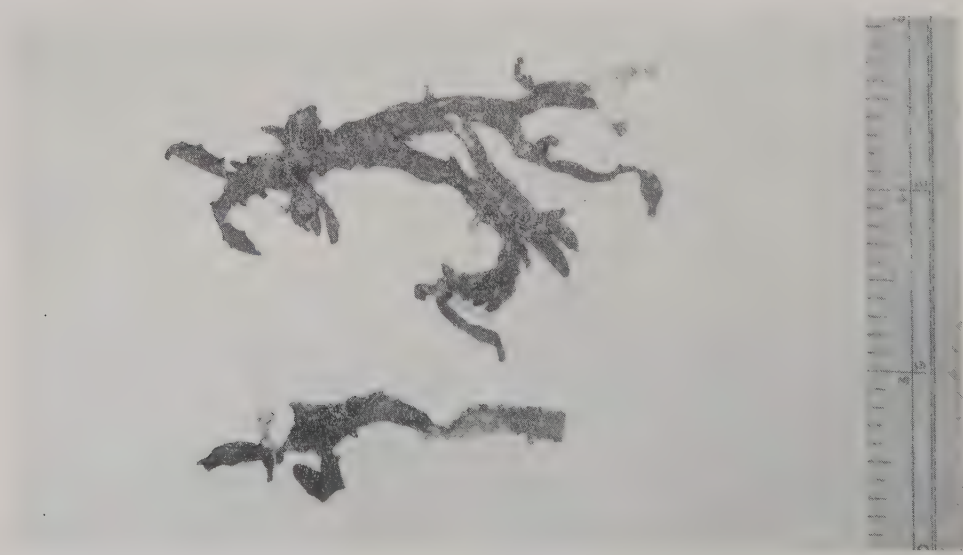

FIG. 2.—*Gracilaria canaliculata*, from Cape York, Qld. (MEL.) (Sonder's specimen.)

PLATE 11

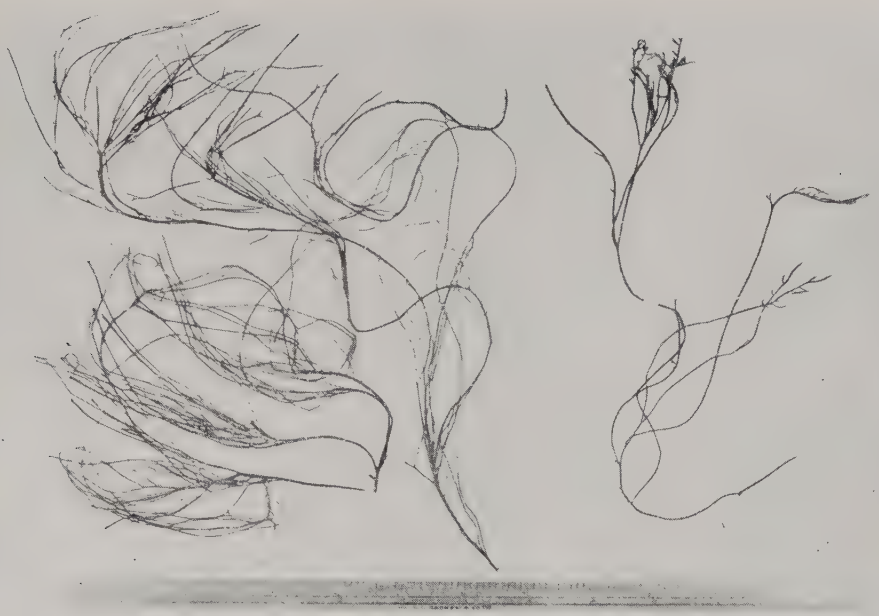

FIG. 1 (left).—*Gracilaria secundata* f. *secundata*, from Newcastle, N.S.W. (MEL). (This specimen is Harvey's Exsicc. No. 325.)

FIG. 2 (right).—*Gracilaria secundata* f. *secundata*, from Brighton, Otaga, N.Z. Ex DSIR 39099a, 4/1940 (VM).

FIG. 3.—*Gracilaria secundata* f. *secundata*, from Maroubra Bay, N.S.W., 10/1931 (SYD).

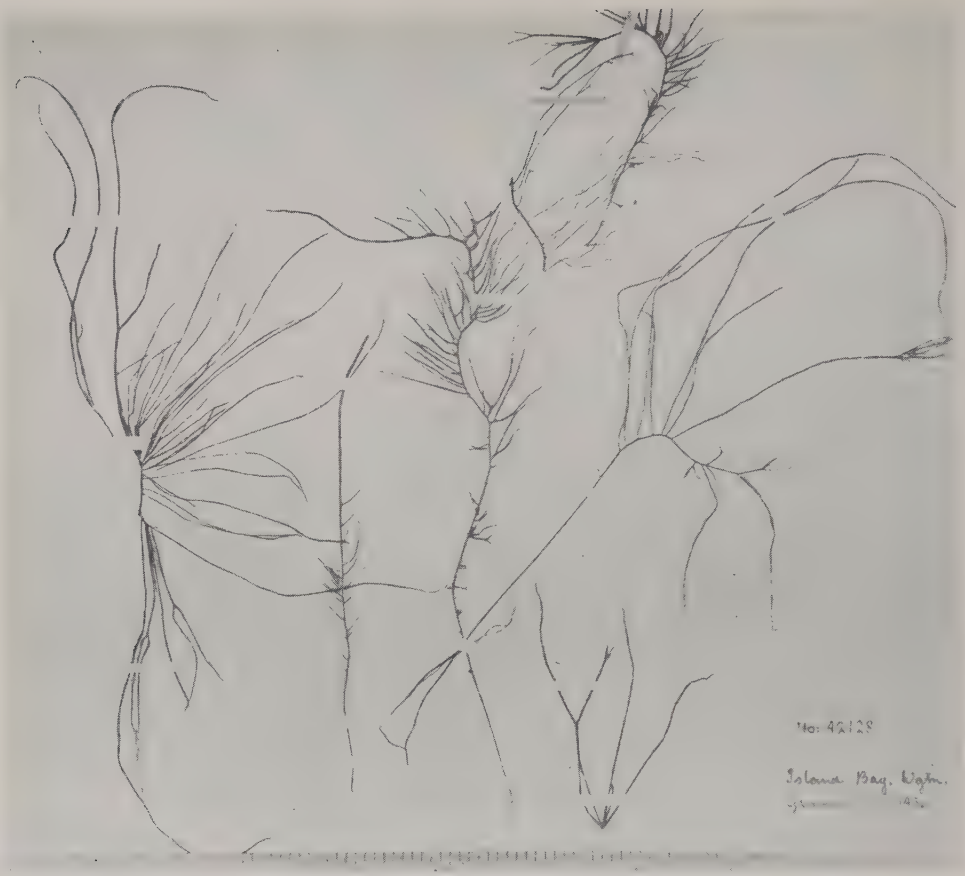


FIG. 1.—*Gracilaria secundata* f. *flagellifera*, from Island Bay, Wellington, N.Z., Ex DSIR 42128, 12/1943 (VM).

FIG. 2.—*Gracilaria secundata* f. *flagellifera*, from Stewart Island, N.Z., Ex VWL 3781, 6/1943 (VM).

PLATE 13

FIG. 1.—*Gracilaria secundata* f. *pseudoflagellifera*, from The Bluff, Ninety-Mile Beach, N.Z., Ex VWL 2088, 1/1941 (VM). (This specimen is the type of the form.)

FIG. 2.—*Gracilaria secundata* f. *pseudoflagellifera*, from Low Head, Tas., 1/1927 (AHSL 5).

PLATE 14

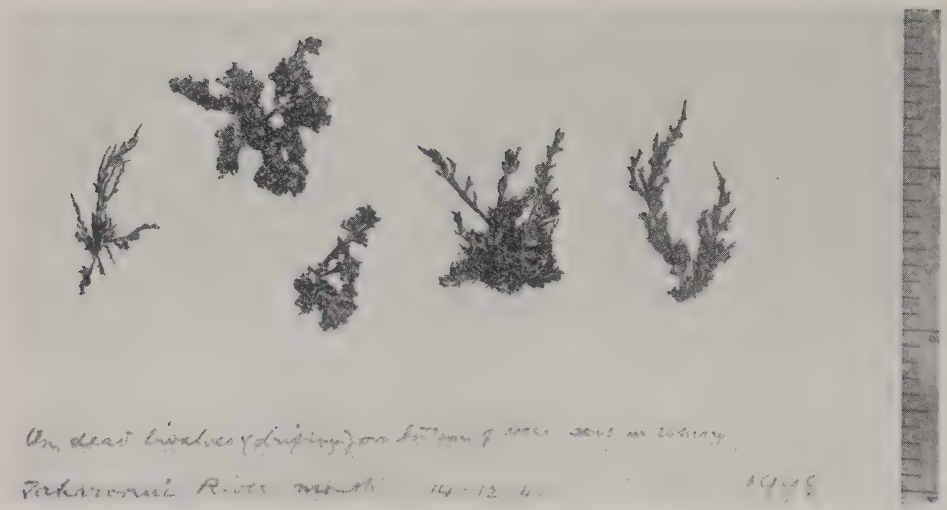

FIG. 1.—*Gracilaria secundata* f. *compacta*, from Taharonui River Mouth, N.Z., Ex VWL 1998, 12/1940 (VM). (The type of the form is highest on the sheet.)

FIG. 2.—*Gracilaria furcellata* f. *ramulosa*, from King George's Sound, W.A. (MEL). (This specimen is Harvey's Exsicc. No. 324.)

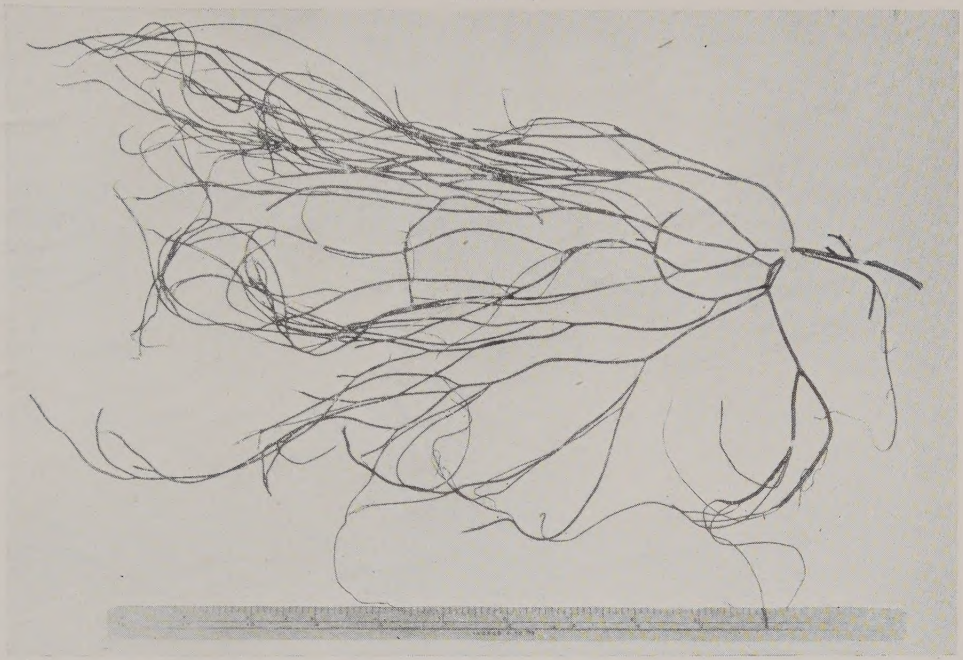

FIG. 1.—*Gracilaria Harveyana* f. *Harveyana*, from Cottesloe, W.A. (UWA).

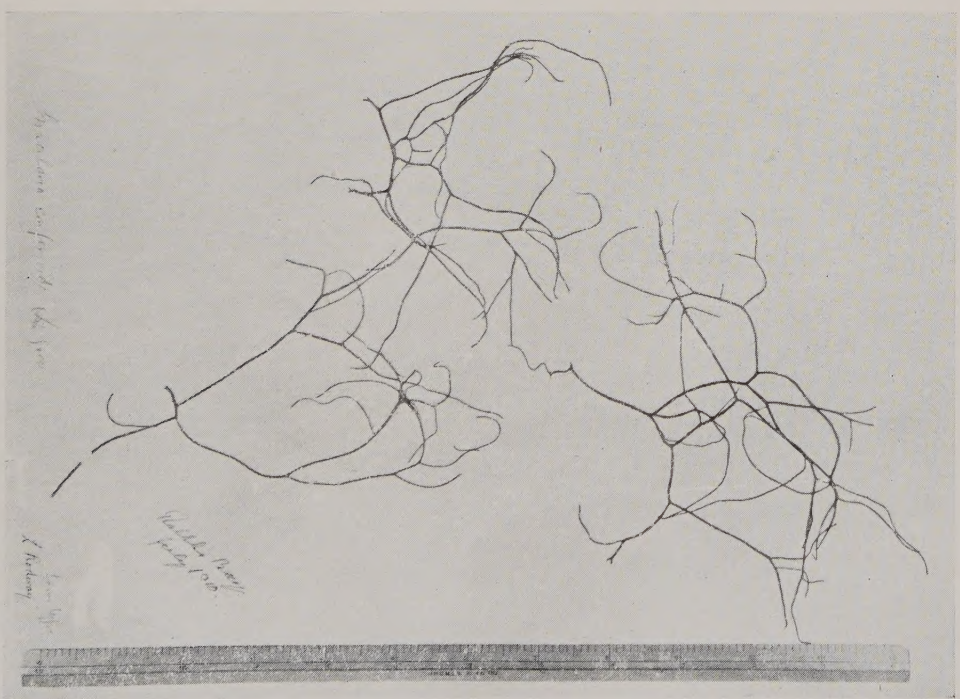

FIG. 2.—*Gracilaria Harveyana* f. *nana*, from Ralph's Bay, Tas., 7/1910 (AHSL). (The type of the form is shown at the left of the sheet.)

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***numbered from 156 onwards.***

**A full list of the Council's publications is issued as a Supplement to the Council's Journal for February each year.**

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158. The Recovery of Inter-block Information in Quasi-Factorial Designs with Incomplete Data. 1.
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160. The Outbreak of the Australian Plague Locust (Chortoicetes terminifera Walk.) in the Season 1939-40, with Special Reference to the Influence of Climatic Factors
161. A Review of the Evidence Concerning Expansive Reaction between Aggregate and Cement in Concrete
162. The Soil and Land-Use Survey of the Wakool Irrigation District, New South Wales
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170. Pea Mosaic on Lupinus varius L. and other species in Western Australia
171. Experiments with Insecticides against the Red-legged Earth Mite (Halotydeus destructor (Tucker))
172. Zebu-cross Cattle in Northern Australia. An Ecological Experiment
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175. The Recovery of Inter-block Information in Quasi-Factorial Designs with Incomplete Data. 2.
176. The Analysis of Cubic Lattice Designs in Varietal Trials
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180. Studies on Deglutition in Sheep. Parts 1 and 2
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182. The Effectiveness of Various Mineral Dusts for the Control of Grain Pests
183. Experimental Determination of the Influence of the Red-legged Earth Mite (Halotydeus destructor) on a Subterranean Clover Pasture in Western Australia
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185. Studies on the Mitchell Grass Association in South-Western Queensland. 2.
186. The General Ecological Characteristics of the Outbreak Areas and Outbreak Years of the Australian Plague Locust (Chortoicetes terminifera Walk.)
187. Alcohol: Its Place in Synthetic Organic Chemical Industry
188. A Soil, Land-Use, and Erosion Survey of Part of County Victoria, South Australia, including the Hundreds of Belalie, Whyte, Reynolds, and Anne, and Part of the Hundreds of Caltowie, Yangya, and Bundaleer
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194. A Procedure of Investigation in Fisheries Biology
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